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IMPACT OF DISPERSION ASSUMPTIONS ON THE ESTIMATED BENEFITS OF REDUCING SO_2 AND PARTICULATE MATTER EMISSIONS

JULY 1990

Ontario
Environment
Environnement
Jim Bradley, Minister/ministre

ISBN 0-7729-7365-2

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Report prepared for:
Policy and Planning Branch
Ontario Ministry of the Environment

JULY 1990

RECYCLABLE

log 90-1104-009
PIBS 1083

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Acknowledgement

Thanks are due to Drs. P.K. Misra and Rob Bloxam for valuable discussion on our data reduction efforts and review of our final selection of sources and associated source data prior to commencement of model runs. We are also grateful to Dr. David Yap and Simon Wong for time and effort expended in providing source characteristic and emission data.

ABSTRACT

A September 1988 report on the Estimated Public Benefits of Implementing the Proposed Revisions to Regulation 308 for the Ministry of the Environment estimated that significant benefits would accrue from lower emissions of sulphur dioxide and particulate matter.

This report examines the impacts of using more accurate stack data and actual emissions, where available, on the estimates of the public benefits attributed to reduced emissions of sulphur dioxide and particulate matter.

The analysis is performed using a stratified random sample of identified sources.

Using stack characteristics and actual emissions for the selected sample of sources and extrapolating to all sources produces estimates that are generally 20 to 25 percent of the values presented in the previous report.

The revised results should still be interpreted as being broad approximations, that provide a rough indication of the nature and magnitude of the public benefits attributable to implementation of the proposed revisions to Regulation 308.

EXECUTIVE SUMMARY

A September 1988 report on the Estimated Public Benefits of Implementing the Proposed Revisions to Regulation 308 for the Ministry of the Environment estimated that significant benefits would accrue from lower emissions of sulphur dioxide and particulate matter.

This report examines the impacts of using more accurate stack data and actual emissions, where available, on the estimates of the public benefits attributed to reduced emissions of sulphur dioxide and particulate matter.

The analysis is performed using a stratified random sample of identified sources. The 19 sources selected for the sulphur dioxide sample collectively emit 56.9 percent of the total estimated emissions affected by the proposed revisions to Regulation 308. The 29 sources selected for the particulate matter sample emit 32.4 percent of the total emissions affected by the proposed revisions to Regulation 308.

The selected establishments presented a combined total of 265 individual stacks. In principle, each stack should be modelled separately. Since that would create an unmanageable workload, stacks with similar characteristics were grouped. A total of 49 different stack types were defined for the 29 sources.

All of the 105 stacks of less than 30 m were treated as virtual sources with the same dispersion pattern. The remaining 160 stacks were grouped (per plant) according to characteristics such as height, temperature, contribution to total plant emissions, etc. The emissions were pooled accordingly.

Three analyses are performed separately for sulphur dioxide and particulate matter and their respective categories of public benefits. They are:

- determination of benefits for the sample sources using estimated emissions and the previous dispersion patterns for comparison with the benefits calculated previously using all sources. This gives an indication of the representativeness of the sample.

- determination of benefits for the sample sources using estimated emissions and the new dispersion patterns for comparison with the sample results calculated above. This gives an indication of the impact of stack characteristics assumptions on the benefits estimates.

- determination of benefits for the sample sources using actual emissions and the new dispersion patterns for comparison with the results calculated above. This gives an indication of the impact of using actual emissions data on the benefits estimates.

In addition, the derivation and application of all exposure-response functions was verified. This study uses exposure-response functions derived from macro-epidemiological studies. And it assumes that health and other benefits occur at below threshold concentrations. Further, the exposure-response functions are assumed to be linear and to be independent for each contaminant. If, contrary to these assumptions, benefits can be realized only above some threshold level, then the benefits will be somewhat smaller than the estimates presented.

Using stack characteristics and actual emissions for the selected sample of sources and extrapolating to all sources produces the following estimates of the public benefits associated with the proposed revisions to Regulation 308.

SULPHUR DIOXIDE

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	56	70	19	19
Reduction in Hospital Days for Respiratory Conditions	1,341	1,686	448	460
Reduction in Hospital Admissions for Respiratory Disease	36	171	45	47
Value of Reduced Mortality (millions of 1986 $)	$ 123 - $ 389	$ 155 - $ 489	$ 41 - $ 130	$ 42 - $ 134
Value of Non-Lethal Health Benefits (millions of 1986 $)	$1 - $3	$1 - $4	< $1	< $1

PARTICULATE MATTER

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	11	12	5	8
Reduction in Emergency Room Visits	637	681	321	492
Reduction in Restricted Activity Days	133,500	142,500	67,000	103,000
Value of Reduced Mortality (millions of 1986 $)	$ 24 - $ 76	$ 26 - $ 83	$ 11 - $ 35	$ 18 - $ 56

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Value of Non-Lethal Health Benefits (millions of 1986 $)	$1 - $8	$2 - $9	$1 - $4	$1 - $6
Reduced Materials Damage (millions of 1986 $)	$1 - $18	$1 - $19	$1 - $9	$1 - $14

These estimates are generally 20 to 25 percent of the values presented in the previous report.

Some unknown fraction of the emissions of each source are deposited outside the 25 km radius area covered by the dispersion model. Those emissions are lost to the benefit calculation, so the benefits are understated. Using actual stack characteristics raises the fraction of the emissions deposited outside the 25 km radius area by an unknown degree. This understates the benefits further and overstates the difference between the results reported in the previous study and those calculated using actual stack and emissions data.

We recommend that the estimated visibility benefits for particulate matter be dropped from the analysis.

The revised results should still be interpreted as being broad approximations, that provide a rough indication of the nature and magnitude of the public benefits attributable to implementation of the proposed revisions to Regulation 308.

1.0 INTRODUCTION

A September 1988 report on the Estimated Public Benefits of Implementing the Proposed Revisions to Regulation 308 for the Ministry of the Environment estimated that significant benefits would accrue from lower emissions of sulphur dioxide and particulate matter. The above study addressed the benefits associated with lower emissions of almost 100 contaminants resulting from proposed revisions to Regulation 308.

Emissions data and exposure-response functions were not available for many of the contaminants. For those contaminants where benefits could be estimated, reductions in sulphur dioxide and particulate matter emissions dominate the reduced mortality and non-lethal health benefits. Lower particulate matter emissions were also estimated to yield benefits as a result of reduced materials damage and improved visibility.

Overall, sulphur dioxide and particulate matter accounted for 40 to 50 percent of the public benefits associated with implementation of the proposed revisions to Regulation 308 that could be quantified.

The earlier study, of necessity, employed a variety of procedures and assumptions to estimate emissions of each contaminant by establishment and the dispersion of those estimated emissions. In light of the major contribution of sulphur dioxide and particulate matter to the overall benefits, an analysis of the impacts of some of the procedures and assumptions on the benefits estimates is appropriate.

This report examines the impacts of using more accurate stack data and actual emissions, where available, on the estimates of the public benefits. Data on stack characteristics and actual emissions of sulphur dioxide and particulate matter are not available for all of the identified sources. In addition, the computational workload involved in modelling each source is large. Hence, the analysis of the impacts is performed using a stratified random sample of identified sources.[1]

The next chapter discusses the sample selection, consolidation of stack types and dispersion modelling results. The impacts on the benefits estimates are presented in Chapter 3 and 4 for sulphur dioxide and particulate matter respectively. The conclusions are presented in Chapter 5.

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1 A stratified random sample is a sample that draws a different fraction of the population from each of several strata. In this case there are a few large sources of emissions and numerous small sources. Since the benefits are determined by the change in quantity emitted, it is important to ensure that the large sources are included in the sample. Hence, the sources are stratified on the basis of their estimated emissions and the stratified sample includes all of the large sources and a small fraction of the many small sources, see Section 2.5.

2.0 SCOPE AND APPROACH

2.1 Scope of the Earlier Study

The earlier study identified the air quality, health and environmental benefits expected from implementation of proposed revisions to Regulation 308.[2] It covered 96 contaminants emitted by over 3,500 establishments in 48 industries across Ontario. Benefits were estimated under five scenarios for implementation of the proposed revisions. The implementation scenarios are described in Appendix C.

The public benefits of reduced contaminant emissions depend upon:

- the contaminant whose emissions are reduced;
- the change in concentration of that contaminant at each point;
- the population and environmental resources in the areas where concentrations are reduced; and
- the human health and environmental responses to the reduced concentrations.

Data on estimated annual emissions by contaminant for each economic sector, under the present regulations and under the five scenarios for implementation of

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[2] The DPA Group Inc., Estimated Public Benefits of Implementing the Proposed Revisions to Regulation 308, Ontario Ministry of the Environment, September, 1988.

the proposed revisions to Regulation 308, were provided by a related study.[3] The emissions data covered only 54 of the 96 contaminants.

The dispersion of those emissions was estimated using the new models developed by the Ministry of the Environment for use with Regulation 308. The dispersion pattern determined the population and environmental resources exposed to emissions of each contaminant.

Reduced concentrations resulting from lower emissions due to implementation of the proposed revisions to Regulation 308 yield public benefits in the form of:

- lower risk of mortality;
- systemic health benefits;
- fewer exposures to above health-threshold concentrations of contaminants;
- improved visibility;
- less materials damage; and
- smaller areas of agricultural land exposed to above threshold concentrations of contaminants.

Coverage of these benefits was incomplete because our knowledge of the effects of a contaminant is often limited. Possible benefits related to animal (domestic and wildlife) health, commercial forest areas, wilderness areas, aquatic toxicity, surface water and odour were not estimated due to data or methodological limitations.

The absence of an exposure-response function does not mean there is no benefit, and the lack of an economic estimate does not mean the benefit has no value.

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3 It is our understanding that the emissions estimates prepared by Senes Consultants Ltd. are being reviewed by the Ministry of the Environment. This analysis uses the industry totals estimated by Senes and reported in the earlier study.

The study results highlight the few cases where public benefits could be quantified and associated economic values could be estimated. As a result, the benefits were understated.

The results provided a rough indication of the nature and magnitude of the public benefits attributable to implementation of the proposed revisions to Regulation 308. The results are defensible if used properly. They are broad approximations; not precise estimates. Considerable scope for refinement and enhancement remains.

2.2 Estimated Benefits Attributed to Reduced Emissions of Sulphur Dioxide and Particulate Matter

The total value of the public benefits for which an economic value was estimated ranges between \$1.2 and \$4.0 billion annually for the least stringent implementation scenario. The most stringent implementation scenario yielded benefits with an economic value of \$3.3 to \$7.7 billion per year.

Sulphur dioxide and particulate matter are the source of a significant share of these benefits. That is due, in part, to the availability of exposure-response functions for these contaminants and the lack of exposure-response functions for most other contaminants.

The public benefits estimated for the reduction in sulphur dioxide emissions that would be achieved by the proposed revisions to Regulation 308 are as shown in Exhibit 2.1. The benefits stem primarily from reduced mortality. Functions are available to estimate a wider range of benefits due to lower particulate matter emissions. These are also shown in Exhibit 2.1. The particulate matter benefits are dominated by improved visibility, with reduced mortality being the second largest category.

EXHIBIT 2.1: ESTIMATED PUBLIC BENEFITS DUE TO REDUCED EMISSIONS OF SULPHUR DIOXIDE AND PARTICULATE MATTER

SULPHUR DIOXIDE	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/Year)	250	300	97	97
Reduction in Hospital Days for Respiratory Conditions	3,746	4,495	1,458	1,458
Reduction in Hospital Admissions for Respiratory Disease	381	457	148	148
Value of Reduced Mortality (millions of 1986 $)	$ 550 - $1,738	$ 660 - $2,085	$ 213 - $ 674	$ 213 - $ 674
Value of Non-Lethal Health Benefits (millions of 1986 $)	$2 - $9	$3 - $10	$1 - $3	$1 - $3
Economic Value of Reduced Sulphur Dioxide Emissions (millions of 1986 $)	$ 552 - $1,747	$ 663 - $2,095	$ 214 - $ 677	$ 214 - $ 677

PARTICULATE MATTER	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/Year)	50	54	25	36
Reduction in Emergency Room Visits	2,940	3,188	1,492	2,117
Reduction in Restricted Activity Days	616,000	668,000	313,000	443,000
Value of Reduced Mortality (millions of 1986 $)	$ 110 - $ 348	$ 119 - $ 375	$ 55 - $ 174	$ 79 - $ 250
Value of Non-Lethal Health Benefits (millions of 1986 $)	$7 - $38	$7 - $41	$3 - $19	$4 - $27
Improved Visibility (millions of 1986 $)	$ 653 - $1,306	$ 700 - $1,400	$ 328 - $ 657	$ 583 - $1,167
Reduced Materials Damage (millions of 1986 $)	$6 - $83	$6 - $92	$3 - $42	$4 - $60
Economic Value of Reduced Particulate Matter Emissions (millions of 1986 $)	$ 776 - $1,775	$ 832 - $1,908	$ 389 - $ 892	$ 670 - $1,504

Together these two contaminants account for 40 to 50 percent of the total benefits which could be estimated for the lower emissions that would result from implementation of the proposed revisions to Regulation 308. In light of the major contribution of sulphur dioxide and particulate matter to the overall benefits, an analysis of some of the procedures and assumptions used to derive these estimates is appropriate. This is especially true given the estimated impacts of these contaminants on mortality, and the fact that they account for 90 to 95 percent of the total estimated reduction in mortality.

2.3 The Procedure Used to Estimate Public Benefits

To appreciate the potential significance of some of the assumptions used, it helps to understand the method used to estimate the public benefits.

The benefits are estimated using an exposure-response function. Each function determines a particular benefit (e.g., reduced mortality) as a function of the change in concentration of the contaminant and the resources (e.g., population) exposed. The exposure-response functions used for sulphur dioxide and particulate matter are described in Appendix B.

To apply the exposure-response functions it is necessary to know the current concentration of the contaminant at each point, the estimated concentration of the contaminant at each point after the proposed revisions to Regulation 308 have been implemented and the population (or other appropriate environmental resource) at that point. The calculations were performed using a 4 km grid. The current and projected concentrations were calculated at the centre of each grid cell. The change in concentration was assumed to apply to the entire 4 km by 4 km cell. The population exposed is the population of the grid cell. The calculations involve over 15,000 grid cells.

The benefits are a function of the change in contaminant concentration. The proposed revisions to Regulation 308 affect the emissions by a specific establishment. To relate the contaminant emissions to ambient concentrations it is necessary to:

. model the dispersion of emissions over the area surrounding each establishment; and

. aggregate the dispersion patterns for a given contaminant that affect each grid cell centre.

The latter step is a mechanical process. The dispersion modelling, in contrast, is a complex technical exercise that requires extensive data on the characteristics of the stacks, the emission flows and the local meteorological conditions. In the first study several simplifying assumptions were used with respect to stack characteristics and emissions flows to compensate for incomplete data and to ease the computational burden. The primary purpose of this study is to examine the impact of the assumptions relating to stack characteristics.

The emissions of a specific contaminant by an establishment, both at present and under the proposed revisions to Regulation 308, were estimated. A related study provided industry totals for each contaminant at present and for each proposed regulatory scenario.[4] The industry totals were apportioned across the establishments in the industry, usually on the basis of employment. This study also examines the impacts of using actual emissions rather than estimated emissions.[5]

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4 Senes Consultants Ltd., Estimation of Additional Abatement Costs for the Proposed Revisions to Regulation 308, forthcoming.

5 As noted in footnote 3, the industry totals estimated by Senes Consultants Ltd are being reviewed by the Ministry of the Environment. Those industry totals are used in this analysis as well. They are used to derive the estimated emissions by establishment

2.4 The Scope of This Study

This study examines the impact on the benefits estimates for sulphur dioxide and particulate matter of:

. using more accurate data for stack characteristics and emission flows in the dispersion modelling; and

. using actual emissions by establishment rather than the estimated emissions.

In all other respects the procedure described above is unchanged.

The proposed revisions to Regulation 308 were estimated to affect 177 sources of sulphur dioxide, emitting a total of 87,995 tonnes annually. Sources of sulphur dioxide emissions covered by the province's acid rain initiative were excluded because reductions achieved by those sources would not be attributable to the proposed revisions to Regulation 308. Some 1,091 sources of particulate matter emitting 92,208 tonnes annually were included in the earlier public benefits analysis.

Many sources have multiple stacks.[6] In principle, the dispersion of emissions from each stack must be modelled separately. The dispersion modelling was performed

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(source). The actual emissions by establishment (as provided by the Ministry of the Environment) for the establishments in the samples are used to estimate the benefits of lower emissions on the presumption that the Senes estimate of the total emissions by the industry is correct.

6 A source is a separate plant or establishment. A source can have multiple stacks. In the terminology of dispersion modelling each stack is referred to as a source. In this report a source is always an establishment with one or more stacks.

using the new models developed by the Ministry of the Environment for use with Regulation 308. These models operate on a personal computer. Each run can take up to eight hours. Clearly, separate modelling of each of several stacks for roughly 1,100 establishments is a mammoth undertaking. Time and budget constraints did not allow such an undertaking. The results, for smaller sources, would not justify the effort. And, in any event, the requisite stack data are not available for many smaller establishments.

Therefore, the analysis in this study was performed using a stratified random sample of establishments that emit sulphur dioxide and/or particulate matter.

2.5 Sample Selection

The estimated emissions from an individual source vary from a fraction of a tonne to thousands of tonnes per year. The larger sources are more likely to have stack characteristics that differ from those assumed in the dispersion modelling. The largest sources also tend to have the greatest impact in determining the benefits of lower emissions. (Proximity to population centres is the other key variable.) Hence, a stratified sample that ensures higher coverage of the largest sources is adopted for the analysis.

Since virtually all emitters of sulphur dioxide are also sources of particulate matter, the sulphur dioxide sample is selected first and those establishments are then augmented as necessary to get the desired coverage of particulate matter sources. Drawing a completely independent sample of particulate matter sources would increase the dispersion modelling work with no gain in accuracy.

A sample of 20 establishments is desired for the analysis of changes in emissions of sulphur dioxide. The sample is stratified to provide the following coverage:

. all sources with estimated emissions greater than 3,000 tonnes/year	4
. one-third of the sources with estimated emissions between 500 and 3,000 tonnes/year	9
. 5% of the sources with estimated emissions of less than 500 tonnes/year	7
Total sample	20

A sample of 30 establishments is desired for the analysis of changes in emissions of particulate matter. The 20 establishments in the sulphur dioxide sample are also part of the particulate matter sample to reduce the dispersion modelling effort. The particulate matter sample is stratified as follows:

	SO_2 Sample	PM Only	Total
. all sources with estimated emissions greater than 3,000 tonnes/year	1	3	4
. 25% of the sources with estimated emissions between 500 and 3,000 tonnes/year	6	4	10
. 1.5% of the sources with estimated emissions of less than 500 tonnes/year	13	3	16
Total sample	20	10	30

The required stack data were not available for all of the randomly selected establishments. As result, some replacement sources were drawn among the smallest firms and one of the intermediate sources was dropped due to lack of availability of data.

The list of sources selected for the samples is provided in Exhibit 2.2.

EXHIBIT 2.2: SO_2 AND PARTICULATE SOURCES DATA SUMMARY

	PLANT NAME	CITY	FILE NAME	MET. FILE NAME	TOTAL SOx (MT/yr)	TOTAL PARTIC. (MT/yr)	TOTAL NO OF STKS.	NO OF ELEV. SRCS.	NO OF VIRT. SRCS	STK. I.D.	SOx per STK. (MT/yr)	PARTIC. per STK. (MT/yr)	N-SOx FRACTION (g/s-normalized)	N-PART. FRACTION	STACK HEIGHT (m)	EXIT VELOC. (m/s)	STACK RADIUS (m)	EXIT TEMP. (oK)	SAMPLE SOx	SAMPLE Part.
1	ABITIBI PRICE (FWD)	THUNDER BAY			3.0	224.0	3	1	1										SOx	Part.
				THU						1	0.1	90.3	0.033	0.403	34.25	6.48	1.29	307		
				THU						0	2.9	133.7	0.967	0.597	14.00	0.00	0.50	-999		
2	• ATLANTIC PACKAGING	SCARBOROUGH		TOR	0.3	39.6	3	0	1	0	0.3	39.6	1.000	1.000	14.00	0.00	0.50	-999	SOx	Part.
3	• BEAVER WOOD FIBRE	THOROLD		SIM	1.2	1.1	2	2	0										SOx	Part.
										1	1.2	1.1	1.000	1.000	50.00	15.69	0.45	366		
4	BROCKV (NITROCHEM)	MAITLAND			61.9	93.0	6	2	1											Part.
				KIN						5	0.0	90.5	0.000	0.973	41.00	8.36	1.20	327		
				KIN						0	61.9	2.3	1.000	0.027	14.00	0.00	0.50	-999		
5	C-I-L	COURTRIGHT			113.4	365.5	13	8	1										SOx	Part.
				WIN						1	66.0	21.1	0.582	0.058	32.00	21.70	1.50	472		
				WIN						0	47.4	344.4	0.418	0.942	14.00	0.00	0.50	-999		
6	CAN,CEMENT LAFARGE	NR.BATH			1710.0	390.1	14	11	0										SOx	Part.
				KIN						7	0.0	195.7	0.000	0.502	46.00	50.70	0.75	358		
				KIN						9	1710.0	194.4	1.000	0.498	76.00	8.60	1.55	479		
7	• CANADA METAL CO LTD	TORONTO			715.2	81.6	8	1	1										SOx	Part.
				TOR						2	715.2	65.9	1.000	0.808	46.00	31.36	0.90	357		
				TOR						0	0.0	15.7	0.000	0.192	14.00	0.00	0.50	-999		
8	• DOFASCO INC.	HAMILTON			6125.7	1642.5	9	6	1											Part.
				TOR						3	1802.6	5.6	0.294	0.003	44.00	5.09	3.05	477		
				TOR						9	2452.7	326.3	0.400	0.321	69.00	11.75	1.45	450		
				TOR						0	1870.4	1110.4	0.305	0.676	14.00	0.00	0.50	-999		
9	DOMTAR PACK'NG LTD	RED ROCK			647.3	2392.4	1	1	0											Part.
				THU						1	647.3	2392.4	1.000	1.000	50.00	3.00	0.45	366		
10	EDDY FOREST PROD.	ESPANOLA			1379.5	2659.7	4	4	0										SOx	Part.
				SOO						1	1326.6	1998.2	0.962	0.751	77.00	13.91	1.83	477		
				SOO						2	52.9	661.6	0.038	0.249	31.00	5.60	0.92	341		
11	FED.WHITE CEMENT	WOODSTOCK			552.8	23.4	6	2	1										SOx	Part.
				LON						2	152.5	7.3	0.276	0.312	32.60	0.50	0.92	573		
				LON						0	400.3	16.1	0.724	0.688	14.00	0.00	0.50	-999		
12	GREAT LAKES FOREST	THUNDER BAY			2858.3	1624.3	3	3	0										SOx	Part.
				THU						1	1157.1	1.9	0.405	0.001	61.26	3.10	1.98	422		
				THU						2	1701.2	1622.4	0.595	0.999	50.00	7.23	1.22	373		
13	GULF/PETCAN CLARKSN.	MISSISSAUGA			4817.8	389.0	26	11	1										SOx	Part.
				TOR						20	2394.1	63.4	0.497	0.163	70.00	19.70	1.05	356		
				TOR						22	1891.7	294.9	0.393	0.758	31.00	34.80	1.05	49[illegible]		
				TOR						0	532.0	30.7	0.110	0.079	14.00	0.00	0.50	-999		
14	IMPERIAL OIL	SARNIA			19595	134.0	12	12	1										SOx	Part.
				WIN						7	16667.3	116.0	0.851	0.753	91.00	11.20	1.60	617		
				WIN						0	2928.1	38.0	0.149	0.247	14.00	0.00	0.50	-999		
15	INDALLOY LTD	NORTH YORK			0.2	10.3	2	0	1											Part.
				TOR						0	0.2	10.3	1.000	1.000	14.00	0.00	0.50	-999		
16	KIDD CREEK MINES	TIMMINS			4272.2	185.8	6	5	0											Part.
				TIM						4	2785.1	60.7	0.652	0.327	43.00	27.70	0.61	355		
				TIM						5	1487.1	125.1	0.348	0.673	74.00	16.00	0.86	360		

EXHIBIT 2.2: SO_2 AND PARTICULATE SOURCES DATA SUMMARY (Continued)

	PLANT NAME	CITY	FILE NAME	MET. FILE NAME	TOTAL SOx (MT/yr)	TOTAL PARTIC. (MT/yr)	TOTAL NO OF STKS.	NO OF ELEV. SRCS.	NO OF VIRT. SRCS.	STK. I.D.	SOx per STK. (MT/yr)	PARTIC. per STK. (MT/yr)	N-SOx FRACTION (g/s-normalized)	N-PART. FRACTION	STACK HEIGHT (m)	EXIT VELOC. (m/s)	STACK RADIUS (m)	EXIT TEMP. (oK)	SAMPLE SOx	SAMPLE Part.
17	LAKE ONTARIO CEMENT	PICTON		TRE	7748.2	184.5	6	6	0	1	7748.2	184.5	1.000	1.000	37.00	26.20	1.20	450	SOx	Part.
18	LAKEVIEW O.S.	MISSISSAUGA		TOR	43836	800.0	4	4	0	1	43836	800.0	1.000	1.000	150.30	28.80	2.97	411		Part.
19	LENNOX O.S.	BATH		KIN	0.0	0.0	2	2	0	1	0.0	0.0	1.000	1.000	199.00	35.14	3.76	414		Part.
20	MALLETTE KRAFT P&P	SMOOTH ROCK FALLS		TIM	281.1	1806.2	9	7	1	5	251.5	1340.2	0.895	0.742	38.40	14.69	0.46	332	SOx	Part.
				TIM						0	29.6	466.0	0.105	0.258	14.00	0.00	0.50	-999		
21	NANTICOKE O.S.	NANTICOKE		SIM	169000	2400	2	2	0	1	169000	2400	1.000	1.000	198.10	30.50	2.73	394		Part.
22	• NORTHERN PIGMENT LT	TORONTO		TOR	7.1	15.6	7	0	1	0	7.1	15.6	1.000	1.000	14.00	10.80	0.50	547	SOx	Part.
23	ONTARIO PAPER CO LY	THOROLD		SIM	1099.2	5.7	7	7	0	6	1099.2	5.7	1.000	1.000	41.70	25.70	0.54	358		Part.
24	PETROSAR LTD	CORUNNA		WIN	6259.6	807.3	4	2	1	2	4694.2	605.3	0.750	0.750	61.00	6.40	1.40	441	SOx	Part.
				WIN						0	1565.4	201.8	0.250	0.250	14.00	0.00	0.50	-999		
25	POLYSAR LTD	SARNIA		WIN	1630.6	139.2	40	8	0	1	1630.6	139.2	1.000	1.000	91.50	20.00	2.82	443		Part.
26	ST.MARY CEMENT	ST MARY		LON	3194.2	124.0	39	34	1	2	878.9	24.4	0.275	0.197	88.39	3.10	0.38	400	SOx	Part.
				LON						24	2.0	64.6	0.001	0.521	55.78	18.10	0.84	450		
				LON						0	2513.3	35.0	0.724	0.282	14.00	0.00	0.50	-999		
27	• STRATHCONA PAPER CO	NAPANEE		KIN	20.1	1.9	1	0	1	0	20.1	1.9	1.000	1.000	9.10	9.40	0.76	463	SOx	Part.
28	SUNCOR	SARNIA		WIN	2662.0	95.0	20	17	0	1	2393.5	55.0	0.899	0.579	77.72	4.93	1.68	610	SOx	Part.
				WIN						18	268.5	40.0	0.101	0.421	38.10	3.78	0.73	542		
29	TEXACO CAN (NANT.)	NANTICOKE		SIM	6210.0	561.0	3	4	0	1	4716.9	398.4	0.760	0.710	112.00	8.60	3.05	506	SOx	Part.
				SIM						3	1493.1	162.6	0.240	0.290	36.00	4.50	1.05	384		
	# OF PLANTS				TOTAL SOx	TOTAL PARTIC.	# OF STKS	# OF ELEV.	# OF VIRT	# OF RUNS	TOTAL SOx	TOTAL PARTIC.	QC NORMALIZED SOx	TEST PARTIC.	MAX.	MAX.	MAX.	MAX.	NO. OF SOx	NO. OF PART.
	29				284802	17417	764	160	13	49	284802	17417	1.000	1.000	199.00	35.14	3.76	617.00	19	29

NOTES:

*	- New Source Selections/Replac - New Source Selections/Replacement Plants for those without MOE data
STK.I.D.	- Preliminary Selections of Stac - Preliminary Selections of Stack Runs from the MOE database (0 refers to a virtual source, others are elevated sources)
N-	- Normalized SOx and Particula - Normalized SOx and Particulate Emissions per Stack.

Source Runs have been reduced from 264 to 160 by applying the criteria of a building height of 14.0 m. Thus all stacks of elevation less than or equal to 28.0 m become virtual (building wake) sources.

Remaining elevated source runs have been reduced from 160 to 34 by aggregating emissions from individual stacks to stacks of similar characteristics. Additionally where emissions rates for remaining individual stacks are less than 7% of total emissions (SOx OR Particulate), these emissions have been apportioned to the source of nearest characteristics (either elevated or virtual).

Virtual Source Runs would utilize identical building parameters. For example, Toronto meteorology would be used for 6 plants. If building parameters are set to be identical, a single building source run can thus be applied to all 6 plants. Thus the total number of virtual runs drops from 13 to 6. This then reduces the total number of all runs from 49 to 40.

METEOROLOGY FILE ABBREVIATIONS	
KIN	Kingston
LON	London
SIM	Simcoe
SOO	Sault Ste. Marie
THU	Thunder Bay
TIM	Timmins
TOR	Toronto
TRE	Trenton
WIN	Windsor

The distribution of sources achieved for the sulphur dioxide and particulate matter samples is as follows:

	SO_2 Sample	PM Only
. sources with estimated emissions greater than 3,000 tonnes/year	4	4
. sources with estimated emissions between 500 and 3,000 tonnes/year	8	11
. sources with estimated emissions of less than 500 tonnes/year	7	14
Total sample	19	29

2.6 Scaling the Sample to the Population Total

The 19 sources selected for the sulphur dioxide sample collectively emit 56.9 percent of the total estimated emissions affected by the proposed revisions to Regulation 308.[7] The scale factors to adjust the estimated emissions of the sample sources to the estimated emissions of all establishments in the emission size category are as follows:

7 The total estimated emissions of sulphur dioxide are those estimated by Senes Consultants Ltd. for all industries that emit sulphur dioxide and which would be affected by the proposed revisions to Regulation 308. That total is 87,995 tonnes annually.

	Scale Factor[8]
large: over 3,000 tonnes/year	1.0000
intermediate: 500 to 3,000 tonnes/year	3.1353
small: under 500 tonnes/year	9.7715

These scale factors are used to assess the impact of using source specific stack and emissions characteristics.

The actual emissions of sulphur dioxide reported by the Ministry for a specific establishment differ significantly from the estimated emissions.[9] The actual emissions of many of the sample establishments do not fall within the limits of the stratum for which the source was selected, i.e., an establishment selected because it was estimated to be a large (over 3,000 tonnes/year) source might have much lower (under 500 tonnes/year) emissions. When assessing the impact of using actual emissions, the sample sources are treated as random selections from the overall population. The actual emissions from the 19 establishments total

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8 The scale factor is calculated by dividing the estimated emissions of sulphur dioxide from all sources in a size category by the estimated emissions of the sources selected as part of the sample. The four large sources have estimated emissions of 35,170 tonnes per year; all four sources are part of the sample so the estimated emissions are 35,170 tonnes per year and the scale factor is 1.0000. The 27 intermediate sources have combined emissions of 43,870 tonnes annually while the 8 selected for the sample have combined emissions of 13,992 tonnes per year. Hence the scale factor is 43,870/13,992 = 3.1353. Finally, the 146 small sources have combined emissions of 8,955 tonnes per year while the 7 sources selected have total emissions of 916 tonnes annually, giving a scale factor of 9.7715.

9 There are many possible explanations for the differences between the actual and estimated emissions for a given source. The major reason is probably the procedure used to estimate the emissions of a particular establishment from the industry total as estimated by Senes Consultants Ltd. Actual data refer to a specific year and may not be representative of normal operating patterns. Actual emissions data are not available for all establishments, so an estimation procedure had to be used in the earlier study.

53,500 tonnes per year. A factor of 1.6448 is used to scale the sample impacts to the population total.[10]

The 29 sources selected for the particulate matter sample emit an estimated 29,896 tonnes per year, 32.4 percent of the total emissions affected by the proposed revisions to Regulation 308. The scale factors to adjust the estimated emissions of the sample sources to the estimated emissions of all establishments in the emission size category are as follows:

	Scale Factor[11]
large: over 3,000 tonnes/year	1.0000
intermediate: 500 to 3,000 tonnes/year	4.0140
small: under 500 tonnes/year	8.1147

These scale factors are used to assess the impact of using source specific stack and emissions characteristics.

The actual emissions of particulates reported by the Ministry for a specific establishment differ from the estimated emissions. The variations are not as large as in the case of sulphur dioxide, but a number of the selected sources report actual emissions outside the size category for which they were selected. Hence,

10 The estimated emissions from the population of 177 sulphur dioxide sources is 87,995 tonnes annually. The actual emissions by the 19 establishments selected for the sample is 53,500 tonnes per year. Hence, the scale factor is 87,995/53,500 = 1.6448.

11 The scale factors relate the estimated emissions of the sample sources to those of all sources. The four large sources emit 14,975 tonnes of particulate annually. They are all part of the sample so the scale factor is 1.0000. The 38 intermediate sources have combined emissions of 42,924 tonnes per year. The 11 sources included in the sample have combined emissions of 10,694 tonnes annually, giving a scale factor of 42,924/10,694 = 4.0140. The 1,049 small sources have combined emissions of 34,309 tonnes per year. The 14 sources selected for the sample have combined emissions of 4,228 tonnes annually, giving a scale factor of 8.1147.

when assessing the impact of using actual emissions, the sample sources are treated as random selections from the overall population. The actual emissions from the 29 establishments total 17,417 tonnes per year. A factor of 5.2942 is used to scale the sample impacts to the population total.[12]

2.7 Consolidation of Stack Types

Actual stack characteristics were provided by the Ministry for the final sample of 29 sources of sulphur dioxide and/or particulate emissions. The selected establishments presented a combined total of 265 individual stacks. In principle, each stack should be modelled separately. The time and effort involved in modelling 265 sources with different apportionments of emissions for sulphur dioxide and particulate is excessive. To reduce the modelling effort, a more manageable number of representative stacks was developed with the concurrence of the Ministry's Model Development Unit.

A virtual source is one where the dispersion pattern is determined by the building rather than the stack. Sources where the stack height is less than twice the height of the building are modelled as virtual sources. Since the Ministry has no data available on building dimensions, a reasonable assumption of these dimensions was required. A typical virtual source was defined as one of 14 m height, 50 m width, and stack elevation less than 28 m. Thus stacks of less than about 30 m elevation could be considered virtual sources.[13] All of the 105 stacks of less than 30 m were treated as virtual sources with the same dispersion pattern.

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[12] The scale factor is calculated by relating the actual emissions of 17,417 tonnes per year to the estimated total of 92,208 (92,208/17,417 = 5.2942).

[13] Note that the building height chosen was exactly double, and the width one-half of that chosen in the previous study. This simplifies comparisons with the previous effort, and provides additional information on the sensitivity of the dispersion field to building dimensions. See The DPA Group Inc., Estimated Public Benefits of Implementing the Proposed Revisions to Regulation 308, Ontario Ministry of the Environment, September, 1988.

The remaining 160 stacks were grouped (per plant) according to characteristics such as height, temperature, contribution to total plant emissions, etc. The emissions were pooled accordingly. In addition, emissions from "stray stacks", those contributing less that 7 percent of total plant emissions, were distributed among the remaining most-similar stacks or virtual sources.

After the consolidation process had been completed, a total of 49 different stack types were defined for the 29 sources. These are described in Exhibit 2.2. They provide good coverage of high elevated, moderately elevated, low elevated and virtual sources.

2.8 Dispersion Modelling

2.8.1 <u>The Modelling Assumptions Used in the Previous Study</u>

In the previous study, a standard source was defined and modelled for each meteorological area of the province.[14] The dispersion modelling yielded annual average ambient concentration values for an area extending 24 km in each direction from the source. A different dispersion concentration "footprint" was created for each meteorological area. The dispersion of emissions from a particular source was mapped by selecting the footprint for that meteorological area, locating the origin at the emission source and scaling the concentrations for the emission rate of the source establishment.

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[14] Every source was assumed to have the following characteristics for the purposes of dispersion modelling. The source was assumed to be a typical "industrial park" building with a height of 7 m, a width of 100 m and a stack height of less than 14 m. Emissions are assumed to exit the stack with a velocity of 0 and at ambient exit temperature.

Project scheduling, scope, and data availability at that time did not allow for actual source parameters to be used in the dispersion modelling. Since about 95 percent of the sources in the province emit under virtual source conditions, a typical source was defined as a building of 7 m height, 100 m width, and less than 14 m stack elevation. It was intended that the enhanced building width in this definition would offset to some degree the variability in actual building heights.

Modelling was performed on a 2 km-resolution receptor grid with near-source resolution increased to 500 m and 1,000 m. Since the largest discrepancies between modelled and actual concentrations would be expected to occur inside a 2-3 km radius of an elevated source (~5% of the sources in Ontario), some additional approximations were suggested to offset artificially enhanced concentrations near the source.

For the analysis of public benefits the study reduced the modelled resolution to 4 km on a 48 x 48 km grid. This coincided with the best grid resolution for which population and establishment distribution data were available and also resulted in lower discrepancies between modelled and actual concentrations for the 5 percent of sources which were elevated.

2.8.2 The Modelling Assumptions Used in the Present Study

The meteorology developed previously was used in the present study. Receptor grid resolution was set at 4 km on a 48 x 48 km grid to correspond with the resolution used previously and to facilitate the subsequent benefits analysis.

In the present case, a dispersion field (footprint) was generated for each source at each plant (i.e., 49 in total). As previously, annual average concentrations were generated at each grid point.

Each stack at each plant was assigned an emission rate of 1 g/s.[15] Apportionment of emissions from the stacks at each plant was normalized for each of sulphur dioxide and particulate emissions. The 1 g/s footprints are scaled down, and superimposed to yield a summary footprint equivalent to a total 1 g/s plant emission rate. The summary footprint is different for sulphur dioxide and particulate matter because the proportion of emissions from each stack is not the same for these two contaminants.

The appropriate summary footprint is scaled according to the total plant emissions of sulphur dioxide or particulate matter.

The models are limited to dispersion over a 25 km radius. Beyond this radius the mathematics become unstable. Small quantities of contaminants are dispersed beyond 25 km. These quantities increase with stack height. The quantities dispersed beyond 25 km are "lost" to the benefit calculation.[16] The impact of this effect can not be estimated.

2.9 Analyses

Three analyses are performed separately for sulphur dioxide and particulate matter and their respective categories of public benefits. They are:

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[15] The assumption of a uniform emission rate is necessary due to lack of data and for computational simplicity. Data on the hourly emission rate by stack are not available. If such data were available, the dispersion of emissions from each stack would be unique, because the dispersion depends upon the meteorological conditions prevailing at the time the emissions occur. The analysis uses only annual average ambient concentrations. It is assumed that fluctuations in the emission rate would be dampened by the averaging process. With a uniform emission rate, the same dispersion footprint can be applied to all stacks with similar characteristics in the same meteorological area. The ambient concentrations do reflect differences in the total quantity emitted from each stack.

[16] Technically the modelled concentration at 24 km from the source is applied over a 4 km grid cell that lies between 22 km and 26 km from the source.

. determination of benefits for the sample sources using estimated emissions and the previous dispersion footprints for comparison with the benefits calculated previously using all sources. This gives an indication of the representativeness of the sample.

. determination of benefits for the sample sources using estimated emissions and the new dispersion footprints for comparison with the sample results calculated above. This gives an indication of the impact of stack characteristics assumptions on the benefits estimates.

. determination of benefits for the sample sources using actual emissions and the new dispersion footprints for comparison with the results calculated above. This gives an indication of the impact of using actual emissions data on the benefits estimates.

In addition the derivation and application of all exposure-response functions was verified. These functions are attached as Appendix B.

The impact of the proposed revisions to Regulation 308 on current actual emissions was assumed to be the percentage reduction estimated by Senes Consultants for the relevant industry. Actual emissions for sample establishments may be higher or lower than those estimated from the industry totals. These differences may be due to many factors including the control technology currently installed. Regardless of the actual emissions it is assumed that they are reduced at each establishment by the same percentage as estimated by Senes Consultants for the industry as a whole.

2.10 Discussion of Dispersion Modelling Results

Comparison was made between previous study output and present study output for a virtual source in Toronto. A point by point comparison is presented in Exhibit 2.3. "TOR-PREV" refers to the previous study, while "AST80386" and "H-R80386" refer to the present study. This showed that the doubling of building height and halving of building width resulted in output concentration data on the 4 km resolution grid that was within about $\pm$ 4 percent of previous results. This agreed with expectations for these sources confirming that the previous building source assumptions would yield representative dispersion footprints for most virtual sources in Ontario.

Output for several multi-source plants was tabulated and individual receptor concentrations were inspected and compared. Anticipated trends in comparing high-elevated, moderately elevated, and virtual source-generated receptor concentrations were confirmed.

An example is provided in Exhibit 2.4. While it is generally the case that annual average ambient concentrations resulting from virtual source assumptions exceed those resulting from elevated source assumptions (on the 48 x 48 km, 4 km resolution grid), it can be observed that for 10 to 15 percent of the receptors, the reverse is true.

Comparing elevated and virtual source effects on annual average ambient concentrations in this example:

- For half to two thirds of the receptors, elevated source results are within a factor of 2 of the virtual source results.

COMPARISON OF CURRENT RUNS WITH PREVIOUS (1988) RUNS TORONTO VIRTUAL SOURCE

X	Y	AS180386	B-880386	TOR-PREV	% DIFFERENCE
-24000	-24000	0.001209	0.001209	0.001214	0.38
-20000	-24000	0.001069	0.001069	0.001072	0.35
-16000	-24000	0.002162	0.002162	0.002172	0.46
-12000	-24000	0.002518	0.002518	0.002527	0.37
-8000	-24000	0.003400	0.003400	0.003410	0.35
-4000	-24000	0.003676	0.003876	0.003890	0.36
0	-24000	0.005417	0.005417	0.005446	0.53
4000	-24000	0.006323	0.006323	0.006352	0.43
8000	-24000	0.009402	0.009402	0.009441	0.41
12000	-24000	0.007952	0.007952	0.007987	0.44
16000	-24000	0.006983	0.006983	0.007008	0.35
20000	-24000	0.005115	0.005115	0.005136	0.43
24000	-24000	0.003107	0.005107	0.003116	0.29
-24000	-20000	0.000787	0.000787	0.000789	0.27
-20000	-20000	0.001546	0.001546	0.001553	0.46
-16000	-20000	0.001486	0.001486	0.001493	0.45
-12000	-20000	0.002875	0.002875	0.002888	0.47
-8000	-20000	0.004774	0.004774	0.004793	0.40
-4000	-20000	0.003917	0.003917	0.003934	0.43
0	-20000	0.006968	0.006968	0.007013	0.65
4000	-20000	0.008296	0.008296	0.008330	0.53
8000	-20000	0.011138	0.011138	0.011192	0.49
12000	-20000	0.013250	0.013250	0.013329	0.59
16000	-20000	0.007045	0.007045	0.007084	0.54
20000	-20000	0.004144	0.004144	0.004159	0.38
24000	-20000	0.002810	0.002810	0.002819	0.31
-24000	-16000	0.000726	0.000726	0.000728	0.30
-20000	-16000	0.000934	0.000934	0.000937	0.35
-16000	-16000	0.002113	0.002113	0.002125	0.58
-12000	-16000	0.002423	0.002423	0.002437	0.59
-8000	-16000	0.004723	0.004723	0.004750	0.58
-4000	-16000	0.004473	0.004473	0.004507	0.76
0	-16000	0.009522	0.009522	0.009601	0.82
4000	-16000	0.012953	0.012953	0.013021	0.52
8000	-16000	0.014949	0.014949	0.015053	0.69
12000	-16000	0.008725	0.008725	0.008783	0.66
16000	-16000	0.005921	0.005921	0.005949	0.47
20000	-16000	0.004765	0.004765	0.004787	0.46
24000	-16000	0.003515	0.003515	0.003532	0.48
-24000	-12000	0.000947	0.000947	0.000951	0.37
-20000	-12000	0.001179	0.001179	0.001182	0.25
-16000	-12000	0.002415	0.002415	0.002434	0.79
-12000	-12000	0.003216	0.003216	0.003241	0.77
-8000	-12000	0.006173	0.006173	0.006232	0.96
-4000	-12000	0.009891	0.009891	0.010002	1.10
0	-12000	0.014386	0.014386	0.014545	1.09
4000	-12000	0.027545	0.027545	0.027799	0.91
8000	-12000	0.019971	0.019971	0.020138	0.83
12000	-12000	0.009426	0.009426	0.009489	0.66
16000	-12000	0.007316	0.007316	0.007342	0.43
20000	-12000	0.007238	0.007238	0.007286	0.65
24000	-12000	0.003968	0.003968	0.003985	0.44
-24000	-8000	0.000603	0.000603	0.000604	0.17
-20000	-8000	0.001510	0.001510	0.001517	0.47
-16000	-8000	0.001714	0.001714	0.001774	0.59
-12000	-8000	0.002750	0.002750	0.002771	0.77
-8000	-8000	0.005986	0.005986	0.006054	1.14
-4000	-8000	0.014064	0.014064	0.014739	1.71
0	-8000	0.026422	0.026422	0.026860	1.63
4000	-8000	0.045877	0.045877	0.046541	1.42

X	Y	AS180386	B-880386	TOR-PREV	% DIFFERENCE
8000	-8000	0.018208	0.018208	0.018397	1.03
12000	-8000	0.012210	0.012210	0.012332	0.99
16000	-6000	0.008286	0.008286	0.008345	0.70
20000	-8000	0.010383	0.010383	0.010457	0.71
24000	-8000	0.007427	0.007427	0.007473	0.61
-24000	-4000	0.001063	0.001063	0.001064	0.11
-20000	-4000	0.001160	0.001160	0.001162	0.19
-16000	-4000	0.001710	0.001710	0.001720	0.61
-12000	-4000	0.002024	0.002024	0.002034	0.49
-8000	-4000	0.005177	0.005177	0.005241	1.22
-4000	-4000	0.016468	0.018469	0.018891	2.23
0	-4000	0.079817	0.079817	0.082418	3.16
4000	-6000	0.056410	0.056410	0.057644	2.14
8000	-4000	0.028786	0.028786	0.029227	1.51
12000	-4000	0.021627	0.021627	0.021896	1.23
16000	-4000	0.011694	0.011694	0.011787	0.79
20000	-4000	0.009369	0.009369	0.009431	0.65
24000	-4000	0.007375	0.007375	0.007417	0.56
-24000	0	0.001217	0.001217	0.001221	0.33
-20000	0	0.001580	0.001580	0.001586	0.41
-16000	0	0.002189	0.002189	0.002200	0.51
-12000	0	0.003375	0.003375	0.003398	0.68
-8000	0	0.006401	0.006401	0.006464	1.01
-4000	0	0.020537	0.020557	0.020962	1.93
0	0	0.000000	0.000000	0.000000	
4000	0	0.175115	0.175115	0.181382	3.46
8000	0	0.056155	0.056155	0.057157	1.75
12000	0	0.029128	0.029120	0.029468	1.15
16000	0	0.018319	0.018310	0.018477	0.85
20000	0	0.012803	0.012803	0.012890	0.67
24000	0	0.009560	0.009560	0.009613	0.55
-24000	4000	0.001788	0.001788	0.001794	0.34
-20000	4000	0.002252	0.002252	0.002262	0.44
-16000	4000	0.003434	0.003434	0.003455	0.60
-12000	4000	0.008826	0.008820	0.008913	0.07
-8000	4000	0.010713	0.010713	0.010838	1.15
-4000	4000	0.029273	0.029273	0.029825	1.85
0	4000	0.114416	0.114416	0.110701	3.61
4000	4000	0.039103	0.039103	0.039912	2.03
8000	4000	0.031107	0.031107	0.031577	1.49
12000	4000	0.017739	0.017739	0.017925	1.04
16000	4000	0.013126	0.013126	0.013227	0.76
20000	4000	0.010210	0.010210	0.010268	0.57
24000	4000	0.007739	0.007739	0.007773	0.44
-24000	8000	0.003445	0.003445	0.003462	0.47
-20000	8000	0.002186	0.002186	0.002194	0.35
-16000	8000	0.003471	0.003471	0.003490	0.33
-12000	8000	0.005765	0.005765	0.005791	0.45
-8000	8000	0.009729	0.009729	0.009809	0.81
-4000	8000	0.022762	0.022762	0.023002	1.04
0	8000	0.037908	0.037908	0.038597	1.79
4000	8000	0.017312	0.017312	0.017599	1.45
8000	8000	0.012360	0.012360	0.012481	0.97
12000	8000	0.012792	0.012792	0.012902	0.85
16000	8000	0.010125	0.010125	0.010203	0.77
20000	8000	0.007424	0.007424	0.007474	0.66
24000	8000	0.005565	0.005565	0.005594	0.52
-24000	12000	0.001030	0.001030	0.001036	0.32
-20000	12000	0.002407	0.002407	0.002412	0.19
-16000	12000	0.004700	0.004700	0.004725	0.53

X	Y	AS180386	B-880386	TOR-PREV	% DIFFERENCE
-12000	12000	0.005116	0.005116	0.005148	0.47
-8000	12000	0.008391	0.008391	0.008443	0.61
-4000	12000	0.014704	0.014704	0.014854	1.01
0	12000	0.019980	0.019980	0.020215	1.13
4000	12000	0.009142	0.009142	0.009235	1.00
8000	12000	0.009090	0.009090	0.009175	0.93
12000	12000	0.006344	0.006344	0.006383	0.61
16000	12000	0.005966	0.005966	0.006002	0.61
20000	12000	0.005347	0.005347	0.005372	0.48
24000	12000	0.005379	0.005379	0.005407	0.51
-24000	16000	0.002365	0.002365	0.002369	0.19
-20000	16000	0.003862	0.003862	0.003880	0.46
-16000	16000	0.003231	0.003231	0.003241	0.31
-12000	16000	0.008528	0.008528	0.008564	0.42
-8000	16000	0.008136	0.008136	0.008170	0.41
-4000	16000	0.009683	0.009683	0.009764	0.83
0	16000	0.012703	0.012703	0.012811	0.84
4000	16000	0.005275	0.005275	0.005305	0.58
8000	16000	0.005697	0.005697	0.005745	0.84
12000	16000	0.003240	0.003240	0.003252	0.39
16000	16000	0.003981	0.003981	0.003998	0.43
20000	16000	0.003864	0.003864	0.003883	0.48
24000	16000	0.004374	0.004374	0.004393	0.41
-24000	20000	0.002331	0.002331	0.002338	0.29
-20000	20000	0.002263	0.002263	0.002268	0.21
-16000	20000	0.006075	0.006075	0.006099	0.39
-12000	20000	0.005532	0.005532	0.005558	0.47
-8000	20000	0.005788	0.005788	0.005810	0.37
-4000	20000	0.005400	0.005400	0.005429	0.54
0	20000	0.008973	0.008973	0.009032	0.65
4000	20000	0.005286	0.005286	0.005320	0.63
8000	20000	0.003087	0.003087	0.003100	0.42
12000	20000	0.003404	0.003404	0.003422	0.53
16000	20000	0.001819	0.001819	0.001822	0.16
20000	20000	0.002784	0.002784	0.002793	0.32
24000	20000	0.002819	0.002819	0.002830	0.40
-24000	24000	0.001697	0.001697	0.001700	0.15
-20000	24000	0.003712	0.003712	0.003725	0.33
-16000	24000	0.002641	0.002641	0.002648	0.27
-12000	24000	0.004558	0.004558	0.004568	0.22
-8000	24000	0.005184	0.005184	0.005208	0.45
-4000	24000	0.005242	0.005242	0.005267	0.48
0	24000	0.006777	0.006777	0.006812	0.52
4000	24000	0.003518	0.003518	0.003536	0.52
8000	24000	0.003136	0.003134	0.003152	0.49
12000	24000	0.002974	0.002974	0.002991	0.35
16000	24000	0.003190	0.003190	0.003205	0.47
20000	24000	0.001550	0.001550	0.001553	0.22
24000	24000	0.002084	0.002084	0.002089	0.25

NOTE:
- X and Y are coordinates in units of Km.
- AS180386 refers to DPA computer.
- B 880386 refers to MOE computer.
- % Difference is 100x(Prev Row)/Prev.
- All units are ug/m3 (per g/s emitted).

EXHIBIT 2.4: COMPARISON OF ELEVATED AND VIRTUAL SOURCES ON A 4-KM RECEPTOR GRID (PETROCANADA, CLARKSON)

Distances (Km)		Concentrations (ug/m3)			%Difference	%Difference
X	Y	70m Stack	51m Stack	Bldg.Wake	Bldg.-70m	Bldg.-51m
-24000	-24000	0.001112	0.000882	0.001209	8.05	27.09
-20000	-24000	0.001055	0.000828	0.001069	1.26	22.56
-16000	-24000	0.001306	0.001092	0.002162	39.59	49.48
-12000	-24000	0.001470	0.001234	0.002518	41.63	51.01
-8000	-24000	0.001564	0.001353	0.003400	53.99	60.22
-4000	-24000	0.002259	0.001923	0.003876	41.71	50.37
0	-24000	0.003163	0.002798	0.005417	41.61	48.35
4000	-24000	0.004537	0.003981	0.006523	30.44	38.97
8000	-24000	0.005133	0.004511	0.009402	45.40	52.02
12000	-24000	0.004771	0.004165	0.007952	40.00	47.62
16000	-24000	0.003251	0.002798	0.006983	53.44	59.93
20000	-24000	0.002864	0.002533	0.005115	44.01	50.48
24000	-24000	0.001719	0.001535	0.003107	44.69	50.60
-24000	-20000	0.001121	0.000940	0.000787	-42.47	-19.42
-20000	-20000	0.001327	0.001050	0.001546	14.16	32.06
-16000	-20000	0.001392	0.001096	0.001486	6.34	26.23
-12000	-20000	0.001813	0.001500	0.002875	36.94	47.82
-8000	-20000	0.002007	0.001654	0.004774	57.96	65.77
-4000	-20000	0.002441	0.002014	0.003917	37.69	48.59
0	-20000	0.003904	0.003395	0.006968	43.97	51.28
4000	-20000	0.005146	0.004459	0.008294	37.96	46.24
8000	-20000	0.005473	0.004764	0.011138	50.86	57.23
12000	-20000	0.005433	0.004566	0.013250	59.00	65.54
16000	-20000	0.003770	0.003290	0.007045	46.49	53.30
20000	-20000	0.002157	0.001891	0.004144	47.95	54.36
24000	-20000	0.002197	0.001990	0.002810	21.83	29.18
-24000	-16000	0.000850	0.000689	0.000726	-17.06	5.11
-20000	-16000	0.001377	0.001138	0.000934	-47.48	-21.83
-16000	-16000	0.001658	0.001303	0.002113	21.53	38.35
-12000	-16000	0.001816	0.001410	0.002423	25.04	41.60
-8000	-16000	0.002258	0.001808	0.004723	52.19	61.72
-4000	-16000	0.002547	0.002125	0.004473	43.06	52.50
0	-16000	0.005026	0.004269	0.009522	47.22	55.17
4000	-16000	0.006273	0.005159	0.012953	51.57	60.17
8000	-16000	0.006803	0.005610	0.014949	54.50	62.47
12000	-16000	0.004467	0.003804	0.008725	48.81	56.40
16000	-16000	0.002832	0.002427	0.005921	52.17	59.01
20000	-16000	0.002609	0.002316	0.004765	45.25	51.40
24000	-16000	0.002456	0.002313	0.003515	30.14	34.21
-24000	-12000	0.001093	0.000945	0.000947	-15.34	0.21
-20000	-12000	0.001200	0.000985	0.001179	-1.77	16.51
-16000	-12000	0.001610	0.001294	0.002415	33.34	46.42

Distances (Km)		Concentrations (ug/m3)			%Difference	%Difference
X	Y	70m Stack	51m Stack	Bldg.Wake	Bldg.-70m	Bldg.-51m
-12000	-12000	0.002227	0.001717	0.003216	30.75	46.59
-8000	-12000	0.002682	0.002092	0.006173	56.55	66.11
-4000	-12000	0.003280	0.002595	0.009891	66.84	73.76
0	-12000	0.006887	0.005651	0.014386	52.13	60.72
4000	-12000	0.010228	0.008283	0.027345	62.87	69.93
8000	-12000	0.006957	0.005494	0.019971	65.16	72.49
12000	-12000	0.003968	0.003301	0.009426	57.91	64.98
16000	-12000	0.003292	0.002939	0.007318	54.99	59.82
20000	-12000	0.003242	0.002961	0.007238	55.21	59.10
24000	-12000	0.002271	0.002108	0.003968	42.78	46.88
-24000	-8000	0.001433	0.001107	0.000603	-137.61	-96.75
-20000	-8000	0.001413	0.001187	0.001510	6.40	21.36
-16000	-8000	0.001735	0.001426	0.001714	-1.24	16.80
-12000	-8000	0.001985	0.001503	0.002700	26.50	44.32
-8000	-8000	0.003365	0.002493	0.005986	43.78	58.36
-4000	-8000	0.004443	0.003246	0.014066	68.41	76.92
0	-8000	0.010417	0.008091	0.026422	60.57	69.38
4000	-8000	0.012104	0.009057	0.045877	73.62	80.26
8000	-8000	0.006153	0.004932	0.018208	66.20	72.91
12000	-8000	0.005442	0.004837	0.012210	55.43	60.39
16000	-8000	0.003785	0.003429	0.008286	54.32	58.62
20000	-8000	0.003599	0.003220	0.010383	65.33	68.99
24000	-8000	0.003629	0.003262	0.007427	51.14	56.08
-24000	-4000	0.002436	0.002143	0.001063	-129.16	-101.56
-20000	-4000	0.002484	0.002154	0.001160	-114.08	-85.64
-16000	-4000	0.002602	0.002174	0.001718	-51.48	-26.58
-12000	-4000	0.003077	0.002409	0.002024	-52.01	-18.99
-8000	-4000	0.003544	0.002670	0.005177	31.54	48.42
-4000	-4000	0.006237	0.004228	0.018469	66.23	77.11
0	-4000	0.018378	0.013025	0.079817	76.98	83.68
4000	-4000	0.011597	0.008963	0.056410	79.44	84.11
8000	-4000	0.008598	0.007391	0.028786	70.13	74.32
12000	-4000	0.007441	0.006284	0.021627	65.59	70.94
16000	-4000	0.005532	0.004644	0.011694	52.69	60.29
20000	-4000	0.004300	0.003754	0.009369	54.11	59.93
24000	-4000	0.003368	0.002948	0.007373	54.34	60.03
-24000	0	0.002385	0.002244	0.001217	-96.06	-84.40
-20000	0	0.002995	0.002790	0.001580	-89.62	-76.61
-16000	0	0.003934	0.003616	0.002189	-79.76	-65.24
-12000	0	0.005533	0.005001	0.003375	-63.96	-48.18
-8000	0	0.008732	0.007736	0.006401	-36.42	-20.85
-4000	0	0.017154	0.015082	0.020557	16.55	26.63

EXHIBIT 2.4: COMPARISON OF ELEVATED AND VIRTUAL SOURCES ON A 4-KM RECEPTOR GRID (PETROCANADA, CLARKSON) (Continued)

Distances (Km)		Concentrations (ug/m3)			%Difference	%Difference
X	Y	70m Stack	51m Stack	Bldg.Wake	Bldg.-70m	Bldg.-51m
0	0	0.000000	0.000000	0.000000	0.00	0.00
4000	0	0.025403	0.019856	0.175115	85.49	88.66
8000	0	0.014216	0.011424	0.056155	74.68	79.66
12000	0	0.009608	0.007906	0.029120	67.02	72.86
16000	0	0.007175	0.006022	0.018310	60.84	67.13
20000	0	0.005684	0.004846	0.012803	55.60	62.15
24000	0	0.004682	0.004040	0.009560	51.02	57.74
-24000	4000	0.002609	0.002293	0.001788	-45.94	-28.23
-20000	4000	0.003052	0.002631	0.002252	-35.52	-16.84
-16000	4000	0.003397	0.002912	0.003434	1.09	15.21
-12000	4000	0.005004	0.004234	0.008826	43.31	52.03
-8000	4000	0.006102	0.004742	0.010715	43.04	55.74
-4000	4000	0.008594	0.006233	0.029273	70.64	78.71
0	4000	0.012498	0.008917	0.114416	89.08	92.21
4000	4000	0.016936	0.013677	0.039103	56.69	65.02
8000	4000	0.014812	0.012574	0.031107	52.38	59.58
12000	4000	0.010551	0.008959	0.017739	40.52	49.50
16000	4000	0.007176	0.006122	0.013126	45.33	53.36
20000	4000	0.005623	0.004741	0.010210	44.93	53.56
24000	4000	0.005246	0.004488	0.007739	32.21	42.00
-24000	8000	0.002223	0.001954	0.003445	35.47	43.29
-20000	8000	0.003091	0.002675	0.002186	-41.40	-22.34
-16000	8000	0.003030	0.002457	0.003471	12.71	29.23
-12000	8000	0.004197	0.003338	0.005765	27.21	42.11
-8000	8000	0.004652	0.003676	0.009729	52.18	62.22
-4000	8000	0.006703	0.005120	0.022762	70.55	77.51
0	8000	0.007316	0.005564	0.037908	80.70	85.32
4000	8000	0.007075	0.005729	0.017312	59.13	66.91
8000	8000	0.008141	0.006864	0.012360	34.14	44.47
12000	8000	0.007884	0.006724	0.012792	38.36	47.44
16000	8000	0.006572	0.005794	0.010125	35.10	42.77
20000	8000	0.005991	0.005133	0.007424	19.30	30.60
24000	8000	0.004628	0.004064	0.005565	16.85	26.97
-24000	12000	0.001956	0.001618	0.001830	-6.88	11.59
-20000	12000	0.002683	0.002271	0.002407	-11.43	5.65
-16000	12000	0.003117	0.002587	0.004700	33.68	44.96
-12000	12000	0.003060	0.002546	0.005118	40.18	50.23
-8000	12000	0.004317	0.003438	0.008391	48.56	58.79
-4000	12000	0.004556	0.003706	0.014704	69.01	74.79
0	12000	0.005078	0.004029	0.019980	74.58	79.83
4000	12000	0.004667	0.003785	0.009142	48.95	58.60
8000	12000	0.004800	0.004089	0.009090	47.20	55.02
12000	12000	0.005000	0.004326	0.006344	21.19	31.81
16000	12000	0.004934	0.004277	0.005964	17.26	28.31
20000	12000	0.005246	0.004610	0.005347	1.88	13.78
24000	12000	0.003994	0.003579	0.005379	25.76	33.47
24000	16000	0.002144	0.001851	0.002365	9.26	21.73
20000	16000	0.002309	0.001925	0.003862	40.21	50.15
-16000	16000	0.002233	0.001918	0.003231	30.88	40.59
12000	16000	0.003579	0.002994	0.008528	58.03	64.87

Distances (Km)		Concentrations (ug/m3)			%Difference	%Difference
X	Y	70m Stack	51m Stack	Bldg.Wake	Bldg.-70m	Bldg.-51m
-8000	16000	0.003768	0.003106	0.008136	53.68	61.82
-4000	16000	0.003114	0.002598	0.009683	67.84	73.17
0	16000	0.003864	0.003158	0.012703	69.58	75.14
4000	16000	0.003139	0.002552	0.005275	40.50	51.62
8000	16000	0.003304	0.002792	0.005697	42.00	51.00
12000	16000	0.003607	0.003191	0.003240	-11.35	1.51
16000	16000	0.003468	0.003040	0.003981	12.87	23.63
20000	16000	0.003755	0.003374	0.003864	2.81	12.68
24000	16000	0.003539	0.003170	0.004374	19.10	27.54
-24000	20000	0.002014	0.001796	0.002331	13.60	22.96
-20000	20000	0.001735	0.001524	0.002263	23.33	32.69
-16000	20000	0.002632	0.002171	0.006075	56.67	64.26
-12000	20000	0.003354	0.002796	0.005532	39.38	49.46
-8000	20000	0.002710	0.002379	0.005788	53.18	58.89
-4000	20000	0.002858	0.002387	0.005400	47.07	55.80
0	20000	0.003115	0.002601	0.008973	65.28	71.01
4000	20000	0.002998	0.002494	0.005286	43.28	52.83
8000	20000	0.002570	0.002122	0.003087	16.73	31.25
12000	20000	0.002934	0.002550	0.003404	13.80	25.07
16000	20000	0.002975	0.002634	0.001819	-63.49	-44.79
20000	20000	0.002587	0.002295	0.002784	7.10	17.57
24000	20000	0.002857	0.002640	0.002819	-1.35	6.36
-24000	24000	0.001407	0.001253	0.001697	17.13	26.19
-20000	24000	0.002122	0.001776	0.003712	42.84	52.17
-16000	24000	0.002209	0.001888	0.002641	16.36	28.51
-12000	24000	0.002671	0.002272	0.004558	41.39	50.15
-8000	24000	0.002388	0.002058	0.005184	53.93	60.30
-4000	24000	0.002595	0.002147	0.005242	50.49	59.04
0	24000	0.002611	0.002215	0.006777	61.46	67.31
4000	24000	0.002699	0.002267	0.003518	23.28	35.55
8000	24000	0.002332	0.002026	0.003136	25.64	35.39
12000	24000	0.002084	0.001785	0.002974	29.95	39.99
16000	24000	0.002160	0.001938	0.003190	31.65	39.23
20000	24000	0.002687	0.002432	0.001550	-73.39	-56.91
24000	24000	0.002025	0.001808	0.002084	2.82	13.24

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PLANT I.D.	PLANT NAME	X (m)	Y (m)	STACK HEIGHT (m)	STACK RADIUS (m)	STACK TEMP. (oK)	EXIT VELOC. (m/s)	B/O	BLDG. HEIGHT (m)	BLDG. WIDTH (m)
301302	PETROCANADA CLARKSON	0	0	70.00	1.05	366	19.70	1	14	50
301302	PETROCANADA CLARKSON	0	0	51.00	1.05	401	34.80	1	14	50
301302	GEP BLDG SOURCE	0	0	14.00	0.50	-999	0.00	1	14	50

. The largest absolute differences and larger percentage differences occur at the receptor locations nearest the source.

. The smallest absolute differences and largest percentage differences tend to occur near the grid perimeter.

. 98 percent of the receptor grid concentrations resulting from virtual source assumptions fall within the same order of magnitude as those resulting from elevated source assumptions.

. The taller stack always yields marginally higher resultant concentrations than the shorter (intermediate) stack. This would not generally be the case but can in this instance be attributed to the higher buoyancy and plume rise of the shorter stack.

The changes in the dispersion footprint are only one aspect of the effect of the modelling inputs on the benefits estimates. The other critical factor is how the changes in estimated concentrations are distributed in relation to the population. These effects are analysed in the next two chapters.

3.0 SULPHUR DIOXIDE

Sulphur dioxide causes respiratory problems, is phytotoxic, causes materials damage, and can reduce visibility.

Exposure-response functions for sulphur dioxide are provided in Appendix B with respect to:

- . mortality;
- . hospital days for respiratory conditions; and
- . hospital admissions for respiratory disease.

3.1 Previous Results

Reductions in mortality estimated to result from lower concentrations of sulphur dioxide attributable to implementation of the proposed revisions to Regulation 308 are as follows:

	Reduced Mortality Deaths/Year	Range of Economic Benefits/Year (1986 C$)
Scenarios[17] "A" & "D"	250	\$550 - 1,738 million
Scenario "B"	300	\$660 - 2,085 million
Scenario "C"	97	\$213 - 674 million
Scenario "E"	97	\$213 - 674 million

[17] The scenarios are defined in Appendix C.

The estimated benefits of the proposed revisions to Regulation 308 in the form of reduced hospitalization due to lower sulphur dioxide concentrations are as follows:

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduction in Hospital Days for Respiratory Conditions	3,746	4,495	1,458	1,458
Reduction in Hospital Admissions for Respiratory Disease	381	457	148	148
Value (million 1986 C$)				
. Low[18]	$ 2.5	$ 3.0	$ 1.0	$ 1.0
. Central[18]	$ 8.7	$ 10.4	$ 3.4	$ 3.4

3.2 Revisions to Previous Results

A review of the derivation of the exposure-response function led to a change in the coefficient for the sulphur dioxide mortality equation from 2.672×10^{-5} to 1.670×10^{-5}. The corrected exposure response function is shown in Appendix B.

Minor computational errors were also uncovered that affected all three exposure response functions. These were corrected.

Revised results were calculated using the estimated emissions and the same dispersion footprints used in the Public Benefits study for all sulphur dioxide sources. The revised results are as shown below.

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[18] Low and central refer to the economic values assigned to various categories of benefits, see Section 3.11 and Appendix A of The DPA Group Inc., Estimated Public Benefits of Implementing the Proposed Revisions to Regulation 308, Ontario Ministry of the Environment, September, 1988.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	240	296	81	82
Reduction in Hospital Days for Respiratory Conditions	5,745	7,083	1,936	1,955
Reduction in Hospital Admissions for Respiratory Disease	584	720	197	199
Value of Reduced Mortality (millions of 1986 $)[19]	$ 528 - $1,667	$ 651 - $2,055	$ 178 - $ 562	$ 180 - $ 567
Value of Non-Lethal Health Benefits (millions of 1986 $)[19]	$4 - $13	$5 - $16	$1 - $5	$1 - $5

These results were calculated in exactly the same manner as those presented in the report on the earlier study. The differences are due entirely to correction of the computational error and revision of the mortality exposure-response function.

3.3 Sample Estimation of Benefits

The above benefits were also estimated using the stratified sample of 19 sulphur dioxide sources. These results are calculated using the estimated emissions and the deposition footprints used in the Public Benefits study. The only difference is that these results are estimated using the stratified sample of 19 sources rather than the entire population of 177 sources. The analysis serves as an indicator of how well the stratified sample matches the population totals. The results are shown below:

[19] The range reflects the low and central values of the economic benefits.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	233	289	41	39
Reduction in Hospital Days for Respiratory Conditions	5,586	6,932	971	942
Reduction in Hospital Admissions for Respiratory Disease	568	704	99	96
Value of Reduced Mortality (millions of 1986 $)[20]	$ 513 - $1,621	$ 637 - $2,011	$ 89 - $ 282	$ 87 - $ 273
Value of Non-Lethal Health Benefits (millions of 1986 $)[20]	$4 - $13	$5 - $16	$1 - $2	$1 - $2

The stratified sample provides estimates of benefits which are very close to those obtained using the population totals for Scenarios A&D and B, being within 3 percent of the total in each case.

The sample estimates for Scenarios C and E are approximately half the population totals. The establishments selected for the sample are from industries where the reductions in emissions under Scenarios C and E are smaller than those anticipated for sulphur dioxide emissions generally.

3.4 Impact of the Revised Deposition Footprints

The next step in the analysis is to estimate the above benefits for the stratified sample of 19 sulphur dioxide sources using the estimated emissions and the new

[20] The range reflects the low and central values of the economic benefits.

source-specific deposition footprints. This isolates the impact of the assumptions used in the deposition modelling. The results are presented below.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	54	62	11	11
Reduction in Hospital Days for Respiratory Conditions	1,300	1,491	256	259
Reduction in Hospital Admissions for Respiratory Disease	132	151	26	26
Value of Reduced Mortality (millions of 1986 $)[21]	$ 119 - $ 377	$ 137 - $ 432	$ 23 - $ 74	$ 24 - $ 75
Value of Non-Lethal Health Benefits (millions of 1986 $)[21]	$1 - $3	$1 - $3	< $1	< $1

Changing the deposition modelling assumptions has a significant impact on the results. The benefits obtained using source specific stack and emissions characteristics are roughly one-quarter as large as those obtained using the assumption that all sources have the same characteristics.

This comparison overstates the effect of using more accurate stack data by an unknown amount. Previously all sources were virtual (building) sources. Using actual stack characteristics, significant quantities of sulphur dioxide are emitted from stacks higher than 30 m. A larger, but unknown, fraction of the emissions from higher stacks are deposited outside the model deposition area. Since a smaller fraction of the emissions fall within the modelled footprint, the difference

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[21] The range reflects the low and central values of the economic benefits.

between the previous estimates and the estimates based on actual stack data are overstated.

3.5 Impact of Using Actual Emissions Data

The actual emissions for the 19 sulphur dioxide sources in the sample total 53,500 tonnes per year. The emissions estimated for these sources totalled 50,078 tonnes per year. The total estimated for all sources that would be affected by the revisions to Regulation 308 is 87,995 tonnes per year. This total is assumed to be correct.

The benefits are calculated for the 19 sample sources using the actual emissions and the source specific stack and emissions characteristics. Those results are scaled up to the total emissions of 87,995 tonnes per year. When compared with the results presented above, this analysis isolates the effect of using actual vs. estimated emissions. The results are presented below.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	56	70	19	19
Reduction in Hospital Days for Respiratory Conditions	1,341	1,686	448	460
Reduction in Hospital Admissions for Respiratory Disease	136	171	45	47
Value of Reduced Mortality (millions of 1986 $)[22]	$ 123 - $ 389	$ 155 - $ 489	$ 41 - $ 130	$ 42 - $ 134

[22] The range reflects the low and central values of the economic benefits.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Value of Non-Lethal Health Benefits (millions of 1986 $)[22]	$1 - $3	$1 - $4	< $1	< $1

The impact of using actual emissions is to raise the estimated benefits under all scenarios. The increase is small (less then 5%) for Scenarios A&D, in the range of 10-15 percent for Scenario B and of the order of 75 percent for Scenarios C and E.

The public benefits estimated using the sample sources with their actual emissions and source specific stack and emissions characteristics are slightly less than one-quarter of the revised results (presented in Section 3.2) obtained using the procedures and assumptions of the Public Benefits study.

These calculations also compare the revised deposition footprints with those previously used. And since the revised footprints capture a smaller share of the total emissions, the differences are overstated to an unknown extent.

3.6 Threshold Exceedances of Sulphur Dioxide Concentrations

The Public Benefits study reported areas and populations estimated to be exposed to above threshold concentrations of sulphur dioxide. Those above threshold exposures are presumed to pose risks for both human health and plant life and the revisions to Regulation 308 propose to restrict concentrations to below threshold levels. The areas and population exposed were estimated. But specific health and crop impacts of those above threshold exposures could not be determined due to the lack of appropriate above threshold exposure-response

functions. Consequently, the benefits of reduced exposures also could not be determined or valued.

The use of a sample of sulphur dioxide emission sources does not allow the exposure calculations to be repeated in a meaningful way. That calculation requires that the dispersion patterns of all sources be combined so that the total ambient concentration at each point can be computed. Mixing the dispersion data for sample sources, calculated with actual emissions and actual stack characteristics, with those of the remaining sources, calculated with estimated emissions and assumed stack characteristics, is not meaningful.

4.0 SUSPENDED PARTICULATE MATTER

Suspended particulate matter causes respiratory problems, damages materials and reduces visibility.

Exposure-response functions for suspended particulate matter are available for:

- mortality;
- restricted activity days;
- emergency room visits;
- materials damage; and
- visibility.

These functions are described in Appendix B. As discussed in Section 4.6, the visibility function takes a form that can not be calculated on a sample basis and extrapolated to the population. Hence, the visibility benefits are not addressed in the following sections.

4.1 Previous Results

Reductions in mortality estimated to result from lower concentrations of suspended particulate matter attributable to implementation to the proposed revisions to Regulation 308 are estimated as follows:

	Reduced Mortality Deaths/Year	Range of Economic Benefits/Year (1986 C$)
Scenarios[23] "A" & "D"	50	$110 - 348 million
Scenario "B"	54	$119 - 375 million
Scenario "C"	25	$ 55 - 174 million
Scenario "E"	36	$ 79 - 250 million

The benefits of implementing the proposed revisions to Regulation 308 in the form of lower restricted activity days and emergency room visits due to reduced particulate matter concentrations are estimated to be as follows:

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduction in Emergency Room Visits	2,940	3,189	1,492	2,116
Reduction in Restricted Activity Days	616,000	668,000	313,000	443,000
Value (million 1986 C$)				
. Low[24]	$ 6.6	$ 7.2	$ 3.4	$ 4.7
. Central[24]	$ 37.7	$ 40.9	$ 19.2	$ 27.1

The reduced materials damage estimated to result from lower concentrations of particulate matter attributable to implementation of the proposed revisions to Regulation 308 is as follows:

23 The scenarios are defined in Appendix C.

24 Low and central refer to the economic values assigned to various categories of benefits, see Section 3.11 and Appendix A of The DPA Group Inc., Estimated Public Benefits of Implementing the Proposed Revisions to Regulation 308, Ontario Ministry of the Environment, September, 1988.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduction in Materials Damage (million 1986 C$)				
. Low[25]	$ 5.8	$ 6.3	$ 3.0	$ 4.2
. Central[25]	$ 83.0	$ 90.0	$ 42.1	$ 59.8

The foregoing results replicate the calculations reported in the earlier study. They are identical to those reported in that study with the exception of a few changes due to rounding resulting from the greater precision adopted in the current calculations.

4.2 Sample Estimation of Benefits

The above benefits were also estimated using the stratified sample of 29 particulate matter sources. These results are calculated using the estimated emissions and the deposition footprints used in the previous study. The analysis measures how well the stratified sample matches the population totals. The results are shown below.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	86	90	49	72
Reduction in Emergency Room Visits	5,034	5,276	2,873	4,235
Reduction in Restricted Activity Days	1,055,000	1,105,000	602,000	887,000

[25] Low and central refer to the economic values assigned to various categories of benefits, see Section 3.11 and Appendix A of The DPA Group Inc., Estimated Public Benefits of Implementing the Proposed Revisions to Regulation 308, Ontario Ministry of the Environment, September, 1988.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Value of Reduced Mortality (millions of 1986 $)[26]	$ 189 - $ 598	$ 198 - $ 626	$ 108 - $ 341	$ 158 - $ 500
Value of Non-Lethal Health Impacts (millions of 1986 $)[26]	$ 9 - $ 65	$ 12 - $ 68	$ 6 - $ 37	$ 10 - $ 54
Reduced Materials Damage (millions of 1986 $)[26]	$ 10 - $ 142	$ 10 - $ 149	$ 6 - $ 81	$ 8 - $ 120

The estimates derived from the stratified sample are 65 to 100 percent higher than those based on the population. The difference between the benefits estimated using the stratified sample and those estimated using the entire population of 1,091 sources is largest for Scenarios C and E. Since all of the sample estimates exceed the population figures, it suggests that the sample sources tend to have larger populations within their dispersion areas than is the case for particulate matter sources generally.

The comparison suggests that the establishments in the sample are from industries where the reductions in emissions under Scenarios C and E are smaller than those for particulate matter generally. That was also true of the sulphur dioxide sample. Since the sulphur dioxide sample represents two-thirds of the particulate matter sample it is not so surprising that it is also true for particulates.

[26] The range reflects the low and central values of the economic benefits.

4.3 Impact of the Revised Deposition Footprints

Next, the benefits of reduced particulate emissions are estimated using the stratified sample of 29 sources and their specific deposition footprints, but still using the estimated emissions. This isolates the impact of the assumptions used in the deposition modelling. The results are presented below.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	25	25	18	24
Reduction in Emergency Room Visits	1,463	1,485	1,045	1,391
Reduction in Restricted Activity Days	306,500	311,000	219,000	291,000
Value of Reduced Mortality (millions of 1986 $)[27]	$ 55 - $ 174	$ 55 - $ 174	$ 40 - $ 125	$ 53 - $ 167
Value of Non-Lethal Health Impacts (millions of 1986 $)[27]	$ 3 - $ 19	$ 3 - $ 19	$ 2 - $ 13	$ 3 - $ 18
Reduced Materials Damage (millions of 1986 $)[27]	$ 3 - $ 41	$ 3 - $ 42	$ 2 - $ 30	$ 3 - $ 40

As was the case for the sulphur dioxide sample, changing the deposition modelling assumptions has a significant impact on the results. The benefits estimated using the source specific stack and emissions characteristics are roughly one-third as

[27] The range reflects the low and central values of the economic benefits.

large as those calculated using the assumption that all sources have the same characteristics.

This comparison overstates the effect of using more accurate stack data by an unknown amount. Previously all sources were virtual (building) sources. Using actual stack characteristics, significant quantities of particulates are emitted from stacks higher than 30 m. A larger, but unknown, fraction of the emissions from higher stacks are deposited outside the model deposition area. Since a smaller fraction of the emissions fall within the modelled footprint, the difference between the previous estimates and the estimates based on actual stack data are overstated.

4.4 Impact of Using Actual Emissions Data

The actual emissions of particulate matter for the 29 sources in the sample are 17,417 tonnes per year. The emissions estimated for those sources totalled 29,896 tonnes per year. Total particulate matter emissions estimated for all sources that would be affected by the revisions to Regulation 308 amount to 92,208 tonnes per year. This total is assumed to be correct. This assumption is discussed further below.

The benefits are calculated for the 29 sample sources using the actual emissions and the source specific deposition patterns. Those results are scaled up to the total emissions of 92,208 tonnes per year. When compared with the results presented above, this analysis isolates the effect of using actual vs. estimated emissions. The results are presented below.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	11	12	5	8
Reduction in Emergency Room Visits	637	681	321	492
Reduction in Restricted Activity Days	133,500	142,500	67,000	103,000
Value of Reduced Mortality (millions of 1986 $)[28]	$ 24 - $ 76	$ 26 - $ 83	$ 11 - $ 35	$ 18 - $ 56
Value of Non-Lethal Health Impacts (millions of 1986 $)[28]	$ 1 - $ 8	$ 2 - $ 9	$ 1 - $ 4	$ 1 - $ 6
Reduced Materials Damage (millions of 1986 $)[28]	$ 1 - $ 18	$ 1 - $ 19	$ 1 - $ 9	$ 1 - $ 14

The impact of using actual emissions is to reduce the estimated benefits between 45 and 70 percent depending upon the scenario. This contrasts with the sulphur dioxide sample, where the effect of using actual emissions was to raise the benefits estimates.

It should be noted that the analysis assumes that the estimate of total emissions by all sources that would be affected by the revisions to Regulation 308 is correct. In the case of sulphur dioxide that actual emissions of the sample sources was about 7 percent higher than the estimated emissions for those sources. Using the sample data to estimate a new population total, rather than assuming that the estimated population total is correct would make relatively little difference.

[28] The range reflects the low and central values of the economic benefits.

In the case of particulate matter, the actual emissions of the 29 sample sources amount to only 58 percent of the estimated emissions of those sources. Using the sample data to estimate a new population total, rather than assuming that the estimate population total is correct could have a more significant impact on the benefits estimates.

The public benefits estimated using the sample sources with their actual emissions and source specific stack and emissions characteristics are slightly less than one-quarter of the results obtained using the procedures and assumptions of the Public Benefits study.

These calculations also compare the revised deposition footprints with those previously used. And since the revised footprints capture a smaller share of the total emissions, the differences are overstated to an unknown extent.

The ratio of the public benefits estimated using the sample sources with their actual emissions and source specific stack and emissions characteristics to the public benefits estimated in the Public Benefits study is the same for all scenarios. Coincidentally, it is virtually identical to the relationship that was found for sulphur dioxide. We believe that to be a coincidence rather than a fundamental pattern. It may be due to the extensive overlap between the sulphur dioxide and particulate matter samples.

4.5 Threshold Exceedances of Particulate Matter Concentrations

The earlier study reported areas and populations estimated to be exposed to above threshold concentrations of particulate matter. Those above threshold exposures are presumed to pose risks for human health. Specific health benefits due to reduced exposures to above threshold concentrations were not determined due to the lack of appropriate exposure-response functions.

The use of a sample of particulate matter sources does not allow the above threshold exposure calculations to be repeated in a meaningful way. That calculation requires that the dispersion patterns of all sources be combined so that the total ambient concentration at each point can be computed. Mixing the dispersion data for sample sources, calculated with actual emissions and actual stack characteristics, with those of the remaining sources, calculated with estimated emissions and assumed stack characteristics, is not meaningful.

4.6 Impacts on Visibility

The exposure-response function for visibility (see Appendix B) depends upon the ratio of the particulate matter concentration; the current concentration divided by the estimated concentration after the proposed revisions to Regulation 308 have been implemented. To apply this equation, it is necessary to have the total particulate matter concentration at each point before and after implementation of the proposed revisions to Regulation 308.

Using the sample yields particulate matter concentrations from those sources alone, not the total particulate matter concentration from all sources. The ratio of the before and after concentrations is therefore incorrect. Hence, the impact of the procedures and assumptions used in the previous study on the visibility benefit could not be assessed.

In the process of investigating this question it became apparent that the visibility benefit reported previously is probably significantly overstated. The exposure-response function gives the greatest weight to areas that experience the largest proportional reduction in particulate matter concentration. We found that large proportional reductions often occurred in grid cells where existing particulate matter concentrations were low. The proposed revisions to Regulation 308

reduced these low concentrations significantly, producing large proportional changes and correspondingly large benefits for improved visibility. However, the existing concentrations are so low that it must be questioned whether visibility is hampered at present and consequently whether an improvement can be noticed.

We found no threshold concentrations or other information in the literature that would permit us to adjust the exposure-response function for visibility. We recommend that the estimated visibility benefits for particulate matter be dropped from the analysis.

5.0 CONCLUSIONS

An earlier study for the Ministry identified the air quality, health and environmental benefits expected from implementation of proposed revisions to Regulation 308.[29] That study had to overcome data limitations and methodological issues within tight deadlines. The results were qualified as broad approximations that provide a rough indication of the nature and magnitude of the public benefits of the proposed revisions.

Overall sulphur dioxide and particulate matter accounted for 40 to 50 percent of the estimated benefits that could be quantified. This report examined the impacts of using more accurate stack data and actual emissions instead of estimated emissions on the estimates of the public benefits associated with sulphur dioxide and particulate matter.

5.1 Revised Results

Using stack characteristics and actual emissions for a sample of sources and extrapolating to the population total produces the following estimates of the annual public benefits associated with the proposed revisions to Regulation 308.

[29] The DPA Group Inc., Estimated Public Benefits of Implementing the Proposed Revisions to Regulation 308, Ontario Ministry of the Environment, September, 1988.

SULPHUR DIOXIDE

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	56	70	19	19
Reduction in Hospital Days for Respiratory Conditions	1,341	1,686	448	460
Reduction in Hospital Admissions for Respiratory Disease	36	171	45	47
Value of Reduced Mortality (millions of 1986 $)[30]	$ 123 - $ 389	$ 155 - $ 489	$ 41 - $ 130	$ 42 - $ 134
Value of Non-Lethal Health Benefits (millions of 1986 $)[29]	$1 - $3	$1 - $4	< $1	< $1

PARTICULATE MATTER

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Mortality (Deaths/year)	11	12	5	8
Reduction in Emergency Room Visits	637	681	321	492
Reduction in Restricted Activity Days	133,500	142,500	67,000	103,000
Value of Reduced Mortality (millions of 1986 $)[29]	$ 24 - $ 76	$ 26 - $ 83	$ 11 - $ 35	$ 18 - $ 56
Value of Non-Lethal Health Impacts (millions of 1986 $)[29]	$1 - $8	$2 - $9	$1 - $4	$1 - $6

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[30] The range reflects the low and central values of the economic benefits.

	Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Reduced Materials Damage (millions of 1986 $)[29]	$1 - $18	$1 - $19	$1 - $9	$1 - $14

These estimates are generally 20 to 25 percent of the values presented in the previous report.[31]

Some unknown fraction of the emissions of each source are deposited outside the 25 km radius area covered by the dispersion model. Those emissions are lost to the benefit calculation, so the benefits are understated. Using actual stack characteristics raises the fraction of the emissions deposited outside the 25 km radius area by an unknown degree. This understates the benefits further and overstates the difference between the results reported in the previous study and those calculated using actual stack and emissions data.

The exposure-response function for the visibility effects of particulate matter could not be applied on a sample basis. Investigation found that it imputed large benefits to areas where proportional reductions in particulate were large, but where existing concentrations were already quite small. In our judgement it is not apparent that visibility improvements could be noticed in all of these areas. We recommend that the estimated visibility benefits for particulate matter be dropped from the analysis.

The earlier study reported areas and populations estimated to be exposed to above threshold concentrations of particulate matter and sulphur dioxide. The use of a

[31] The estimates presented in the Public Benefits report are reproduced in Sections 3.1 and 4.1 of this report.

sample of sulphur dioxide or particulate matter sources does not allow the above threshold calculations to be repeated in a meaningful way.

5.2 Interpretation of the Results

The revised results should still be interpreted as being broad approximations, that provide a rough indication of the nature and magnitude of the public benefits attributable to implementation of the proposed revisions to Regulation 308.

In the analysis of the environmental impacts:

- accurate actual data are preferred to estimates; and

- larger samples are preferred to smaller samples.

These propositions remain true. The results presented above do not reflect accurate actual data for, nor complete coverage of, all sources and so could be refined still further. However, the data collection and analytical effort involved is large.

The revised results presented above focused on the dispersion modelling aspects of the analysis. If further refinements are considered it may be appropriate to address other factors that could affect the results, for example:

- source specific estimates of the reduction of emissions that could be achieved under each implementation scenario. The above analysis uses industry averages for all plants.

- finer resolution of the population distribution data so that greater resolution of the dispersion modelling could be meaningfully applied.

- more and better exposure-response functions so that more of the impacts can be quantified with a degree of confidence.

- analysis of fluctuations in emissions and the impacts of short term exposures rather than annual averages.

The revised results remain a useful first approximation of the public benefits of the proposed revisions to Regulation 308.

5.3 Exposure-Response Functions

The review of the exposure-response functions for sulphur dioxide and particulate matter led to two unresolved epidemiological debates.

First, is the issue of thresholds. Threshold concentrations are the only feasible way to regulate contaminants. The threshold established is generally a conservative one. A no observed adverse effect limit (NOAEL) is established using toxicological data and a series of protection or safety factors. The result is then multiplied by a final protection factor (usually 0.1) to protect the most-sensitive population groups. The regulatory thresholds are, therefore, considered by many to be conservative and to offer a high degree of protection for human health.

Nevertheless, epidemiologists we consulted felt that reduced exposures yield health benefits even if the concentrations are below accepted thresholds. In other words, while exposures to below threshold concentrations may be deemed to be "safe" on the basis of current medical knowledge, lower concentrations may still yield health benefits.

Second, is the apparently conflicting evidence of micro- and macro-epidemiological studies. The former are medical studies of relatively small, controlled groups of subjects exposed to different concentrations of contaminants. The latter are statistical analyses of air pollution and human health data for large populations. The micro studies tend to show no direct health problems associated with air pollution levels below current standards. The macro studies show weak but statistically significant relationships between current air pollution levels and human health.

It is worth noting that the coefficients for the health impacts imply that only one person in 10,000 is affected. The micro-epidemiological studies generally deal with smaller groups. This might help to explain the apparent contradiction in the findings of the different types of studies.

The macro studies, by the nature of the statistical techniques used, can not identify cause and effect. The macro studies also can not ensure that the estimated effects are not due to causes that have been overlooked in the analysis. For example, the observed health effects could be due to the combined impact of sulphur dioxide and particulate matter rather than particulate matter alone. The study from which the sulphur dioxide exposure-response function is drawn considered that interaction, but may have done so inadequately or may have omitted other important factors.

This study uses exposure-response functions derived from macro-epidemiological studies. And it assumes that health and other benefits occur at below threshold concentrations. Further, the exposure-response functions are assumed to be linear and to be independent for each contaminant.[32] If, contrary to these assumptions,

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[32] Although it is not directly relevant for sulphur dioxide or particulates, the exposure-response functions for carcinogens are generally agreed to be linear with a zero threshold. However, the unit risk factors used to define those linear relationships are developed in

benefits can be realized only above some threshold level, then the benefits will be somewhat smaller than the estimates presented.

This study estimates benefits from changes in annual average exposures. Reductions in peak exposures may be more critical for some benefits. Very few exposure-response functions use peak concentrations as the basis for estimating benefits. And to compute the changes in peak concentrations using the dispersion model involves a significant increase in effort. As a result benefits were not related to shorter term exposures. This was, however, one of several possible refinements suggested in the earlier study.

much the same way as the threshold values, and so may overstate the benefits of reduced concentrations of carcinogens.

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APPENDIX A

Dispersion Modelling of Selected Sources Of SO_2 Particulate

A.1 INTRODUCTION

This study performed detailed dispersion modelling on a statistically representative selection of sources of SO_2 and particulate matter. The purpose of the work was to analyse the effect of using actual source characteristics rather than standard assumptions of a virtual source on the benefits estimated in an earlier study.

The Public Benefits study concluded that the most significant measurable benefits of implementing proposed changes to Regulation 308 would be expected to be attributed to reductions in emissions of SO_2 and particulate matter.

Since nearly all significant sources of SO_2 and many major sources of particulate matter in Ontario emit from **elevated** sources, it appeared to be desirable to assess the impact of the assumption used in the Public Benefits study that all sources are virtual sources. This, in addition to other considerations, led to the current study.

A.2 BACKGROUND

In the previous study, a typical source was defined and modelled for each meteorological area (met-zone) of the Province. This yielded 48 x 48 km dispersion concentration "footprints" per g/s emitted. Footprints for each met-zone were spatially mapped, scaled, and superimposed to correspond to coordinates and estimated emission rates for source establishments (plants). Project scheduling, scope, and data availability at that time did not allow for actual source parameters to be used in the modelling. Since about 95% of the source plants in the province emit under virtual-source conditions, a typical virtual source was defined to be a building of 7 m height, 100 m width, and 7 m stack elevation

above the building. It was intended that the enhanced building width in this definition of typical would offset to some degree the variability in actual building heights.

Modelling was performed on a 2 km-resolution receptor grid with near-source resolution increased to 500 m and 1,000 m. Since the largest discrepancies between modelled and actual concentrations would be expected to occur inside a 2-3 km radius of an **elevated** source (~5% of the sources in Ontario), some additional approximations were suggested to offset artificially enhanced concentrations near the source.

In the benefits analysis of the study, the decision was made to reduce modelled resolution to 4 km on a 48 x 48 km grid. This coincided with the best grid resolution for which population and establishment distribution data were available and also resulted in reducing the discrepancies between modelled and actual concentrations for the 5% of sources which were elevated.

A.3 DATA SOURCES AND CONSOLIDATION OF STACK TYPES

Actual stack characteristics were provided by the MOE and developed for the final selection of 29 sources of SO_2 and/or particulate matter. The selected plants presented a combined total of 265 individual stacks. As a response to the logistics of modelling 265 sources with different apportionments of emissions for SO_2 and particulate, a data reduction process was developed with the concurrence of the MOE Model Development Unit. The object here was to reduce the number of sources to a manageable number while maintaining a good representation of emission types and apportionments (i.e., among high elevated, moderately elevated, low elevated, and virtual sources at a plant).

Since no MOE data were available on building dimensions, a reasonable assumption of these dimensions was required. A typical virtual source was defined as one of 14 m height, 50 m width, and stack elevation less than 28 m. Thus effectively, stacks of less than about 30 m elevation would be considered virtual sources. Note that the building height chosen was exactly double, and the width one-half of that chosen in the previous study. This simplified comparison with the previous effort, and provide additional information on the sensitivity of the dispersion field to building dimensions.

Using the new definition of a typical building reduced the number of required model runs to 160. Remaining stacks were grouped (per plant) according to characteristics (e.g., height, temperature, contribution to total plant emissions, etc.) and emissions pooled accordingly. In addition, emissions from "stray stacks", those contributing less that 7% of total plant emissions, were distributed among the remaining most-similar stacks or virtual sources. Using a common definition of building source also allowed some model runs from common met-zones (e.g., Toronto) to be combined.

The resultant selection of 49 sources to be modelled (for 29 plants) yielded 40 model runs. The relevant data for these 29 plants (49 sources) is presented in Exhibit A.1.

A.4 MODEL RUNS

The meteorology developed previously was used in the present study. Receptor grid resolution was set at 4 km on a 24 x 24 km grid to correspond with the resolution used previously and to facilitate the subsequent benefits analysis.

EXHIBIT A.1: SO_x AND PARTICULATE SOURCES DATA SUMMARY

	PLANT NAME	CITY	FILE NAME	MET. FILE NAME	TOTAL SOx (MT/yr)	TOTAL PARTIC. (MT/yr)	TOTAL NO.OF STKS.	NO.OF ELEV. SRCS.	NO OF VIRT. SRCS	STK. I D	SOx per STK. (MT/yr)	PARTIC. per STK. (MT/yr)	N-SOx FRACTION (g/s-normalized)	N-PART. FRACTION	STACK HEIGHT (m)	EXIT VELOC. (m/s)	STACK RADIUS (m)	EXIT TEMP. (oK)	SAMPLE SOx	SAMPLE Part.
1	AOITIBI PRICE (FWD)	THUNDER BAY		THU	3 0	224 0	3	1	1	1	0.1	90 3	0 033	0 403	34 25	6 48	1 29	307	SOx	Part.
				THU						0	2 9	133.7	0.967	0.597	14 00	0 00	0 50	-999		
2 •	ATLANTIC PACKAGING	SCARBOROUGH		TOR	0.5	39 6	3	0	1	0	0.3	39 6	1 000	1 000	14 00	0 00	0 50	-999	SOx	Part.
3 •	BEAVER WOOD FIBRE	THOROLD		SIM	1.2	1.1	2	2	0	1	1 2	1.1	1.000	1.000	30 00	15 69	0 43	366	SOx	Part.
4	BROCKV (NITROCHEM)	MAITLAND		KIN	61.9	93.0	6	2	1	5	0 0	90 5	0 000	0 973	41.00	8 36	1 20	327		Part.
				KIN						0	61.9	2 5	1.000	0 027	14.00	0.00	0.50	-999		
5	C-I-L	COURTRIGHT		WIN	115 4	365.5	13	8	1	1	66.0	21 1	0 582	0 058	52 00	21.70	1 50	472	SOx	Part.
				WIN						0	47 4	344 4	0 418	0.942	14 00	0 00	0.50	-999		
6	CAN,CEMENT LAFARGE	NR BATH		KIN	1710 0	590 1	14	11	0	7	0 0	195 7	0.000	0 502	46 00	30 70	0.75	358	SOx	Part.
				KIN						9	1710 0	194 4	1.000	0 498	76 00	8.60	1.55	479		
7 •	CANADA METAL CO LTD	TORONTO		TOR	715 2	81.6	8	1	1	2	715 2	65 9	1.000	0 806	46 00	31.36	0 90	352	SOx	Part.
				TOR						0	0.0	15.7	0 000	0.192	14 00	0.00	0.50	-999		
8 •	DOFASCO INC.	HAMILTON		TOR	6125.7	1642.5	9	6	1	3	1802.6	5 6	0.294	0.003	44 00	5 09	3.05	477		Part.
				TOR						9	2452.7	526 5	0.400	0.321	69 00	11.75	1 45	450		
				TOR						0	1870.4	1110 4	0.305	0.676	14 00	0 00	0.50	-999		
9	DOMTAR PACK'NG LTD	RED ROCK		THU	647.3	2592 4	1	1	0	1	647.3	2592.4	1.000	1.000	30.00	3.00	0 45	366		Part.
10	EDDY FOREST PROD.	ESPANOLA		SOO	1379.5	2659.7	4	4	0	1	1326 6	1998 2	0 962	0 751	77 00	13.91	1 83	477	SOx	Part.
				SOO						2	52.9	661 6	0 038	0.249	31.00	5.60	0 92	341		
11	FED.WHITE CEMENT	WOODSTOCK		LON	552 8	23 4	6	2	1	2	152.5	7 3	0 276	0 312	32 60	0 30	0 92	573	SOx	Part.
				LON						0	400 3	16 1	0.724	0 688	14 00	0 00	0 50	-999		
12	GREAT LAKES FOREST	THUNDER BAY		THU	2858 5	1624 3	5	5	0	1	1157.1	1 9	0 405	0 001	61.26	5 10	1 98	422	SOx	Part.
				THU						2	1701.2	1622 4	0 595	0.999	50 00	7 23	1 27	373		
13	GULF/PETCAN.CLARKSN.	MISSISSAUGA		TOR	4817 8	389 0	26	11	1	20	2394 1	63 4	0 497	0.163	70 00	19 70	1 05	386	SOx	Part.
				TOR						22	1891.7	294 9	0 393	0 758	51 00	34 80	1 05	491		
				TOR						0	532 0	50 7	0 110	0 079	14 00	0 00	0.50	-999		
14	IMPERIAL OIL	SARNIA		WIN	19595	154 0	12	12	1	7	16667 3	116 0	0 851	0 753	91 00	11 20	1 60	617	SOx	Part.
				WIN						0	2928 1	38 0	0 149	0 247	14 00	0.00	0 50	-999		
15	INDALLOY LTD	NORTH YORK		TOR	0 2	10.3	2	0	1	0	0 2	10 3	1 000	1 000	14 00	0 00	0 50	-999		Part.
16	KIDD CREEK MINES	TIMMINS		TIM	4272.2	185 8	6	3	0	4	2785.1	60 7	0 652	0 327	43 00	27.70	0 61	355		Part.
				TIM						5	1487.1	123 1	0 348	0 673	74 00	16 00	0 66	360		

	PLANT NAME	CITY	FILE NAME	MET. FILE NAME	TOTAL SOx (MT/yr)	TOTAL PARTIC. (MT/yr)	TOTAL NO OP STKS.	NO OF ELEV. SRCS.	NO OP VIRT. SRCS.	STK. I.D.	SOx per STK. (MT/yr)	PARTIC. per STK. (MT/yr)	N-SOx FRACTION (g/s-normalized)	N-PART. FRACTION	STACK HEIGHT (m)	EXIT VELOC. (m/s)	STACK RADIUS (m)	EXIT TEMP. (oK)	SAMPLE SOx	SAMPLE Part.
17	LAKE ONTARIO CEMENT	PICTON			7748.2	184.5	6	6	0										SOx	Part.
				TRE						1	7748.2	184.5	1.000	1.000	37.00	26.70	1.20	450		
18	LAKEVIEW G.S.	MISSISSAUGA			43836	800.0	4	4	0											Part.
				TOR						1	43836	800.0	1.000	1.000	150.30	28.80	2.97	411		
19	LENNOX G.S.	BATH			0.0	0.0	2	2	0											Part.
				KIN						1	0.0	0.0	1.000	1.000	199.00	35.14	3.76	414		
20	MALLETTE KRAFT P&P	SMOOTH ROCK FALLS			281.1	1806.2	9	7	1										SOx	Part.
				TIM						3	251.5	1340.2	0.895	0.742	38.40	14.69	0.46	332		
				TIM						0	29.6	466.0	0.105	0.258	14.00	0.00	0.50	-999		
21	NANTICOKE G.S.	NANTICOKE			169000	2400	2	2	0											Part.
				SIM						1	169000	2400	1.000	1.000	198.10	30.50	2.75	394		
22	* NORTHERN PIGMENT LT	TORONTO			7.1	15.6	7	0	1										SOx	Part.
				TOR						0	7.1	15.6	1.000	1.000	14.00	10.80	0.30	547		
23	ONTARIO PAPER CO LT	THOROLD			1099.2	5.7	7	7	0											Part.
				SIM						6	1099.2	5.7	1.000	1.000	41.70	25.70	0.54	358		
24	PETROSAR LTD	CORUNNA			6259.6	807.3	4	2	1										SOx	Part.
				WIN						2	4694.2	605.5	0.750	0.750	61.00	6.40	1.40	441		
				WIN						0	1565.4	701.8	0.250	0.250	14.00	0.00	0.50	-999		
25	POLYSAR LTD	SARNIA			1630.6	139.2	40	8	0											Part.
				WIN						1	1630.6	139.2	1.000	1.000	91.50	20.00	2.92	445		
26	ST.MARY CEMENT	ST.MARY			3194.2	124.0	39	34	1										SOx	Part.
				LON						2	878.9	24.4	0.275	0.197	88.39	5.10	0.38	400		
				LON						24	2.0	64.6	0.001	0.521	35.78	18.10	0.84	450		
				LON						0	2513.3	55.0	0.724	0.282	14.00	0.00	0.50	-999		
27	* STRATHCONA PAPER CO	NAPANEE			20.1	1.9	1	0	1										SOx	Part.
				KIN						0	20.1	1.9	1.000	1.000	9.10	9.40	0.76	465		
28	SUNCOR	SARNIA			2662.0	95.0	20	17	0										SOx	Part.
				WIN						1	2393.5	55.0	0.899	0.579	77.72	4.93	1.68	610		
				WIN						18	268.5	40.0	0.101	0.421	38.10	3.78	0.73	542		
29	TEXACO CAN (NANT.)	NANTICOKE			6210.0	361.0	3	4	0										SOx	Part.
				SIM						1	4716.9	398.4	0.760	0.710	112.00	8.60	3.05	506		
				SIM						3	1493.1	162.6	0.240	0.290	56.00	4.50	1.05	584		
	# OF PLANTS				TOTAL SOx	TOTAL PARTIC	# OF STKS	# OF ELEV.	# OF VIRT	# OF RUNS	TOTAL SOx	TOTAL PARTIC.	QC NORMALIZED SOx	TEST PARTIC.	MAX.	MAX	MAX	MAX.	NO OP SOx	NO OP PART
	29				284802	17417	264	160	15	49	284802	17417	1.000	1.000	199.00	35.14	3.76	617.00	19	29

NOTES

*	- New Source Selections/Replac	-New Source Selections/Replacement Plants for those without MOE data
STK I.D.	- Preliminary Selections of Stac	-Preliminary Selections of Stack Runs from the MOE database (0 refers to a virtual source, others are elevated sources)
N-	- Normalized SOx and Particula	-Normalized SOx and Particulate Emissions per Stack

Source Runs have been reduced from 264 to 160 by applying the criteria of a building height of 14.0 m. Thus all stacks of elevation less than or equal to 28.0 m become virtual (building wake) sources.

Remaining elevated source runs have been reduced from 160 to 34 by aggregating emissions from individual stacks to stacks of similar characteristics. Additionally, where emissions rates for remaining individual stacks are less than 7% of total emissions (SOx OR Particulate), these emissions have been apportioned to the source of nearest characteristics (either elevated or virtual).

Virtual Source Runs would utilize identical building parameters. For example, Toronto meteorology would be used for 6 plants. If building parameters are set to be identical, a single building source run can thus be applied to all 6 plants. Thus the total number of virtual runs drops from 15 to 6. This then reduces the total number of all runs from 49 to 40.

METEOROLOGY FILE ABBREVIATIONS	
KIN	Kingston
LON	London
SIM	Simcoe
SOO	Sault Ste. Marie
THU	Thunder Bay
TIM	Timmins
TOR	Toronto
TRE	Trenton
WIN	Windsor

All original data on stack characteristics and emissions apportionment among stacks are as provided by MOE Air Resources Branch current to 26/05/89

As previously, annual average (.AVG file) concentrations were generated from each individual source. In the present case, a dispersion field (footprint) was generated for each source at each plant (i.e., 49 in total).

Each source at each plant was assigned an emission rate of 1 g/s. Apportionment of emissions from the stacks at each plant were normalized separately for SO_2 and particulate matter emissions. This allowed the 1 g/s footprints to be subsequently scaled down, and superimposed to yield a separate summary footprint equivalent to a total 1 g/s plant emission rate for SO_2 and particulate.

The appropriate summary footprint was then be scaled up or down according to the particular estimate of total plant emissions.

A.5 QUALITY CONTROL

As previously, DOS batch programs were developed to maintain control over file organization, manipulation, and execution. Initial checks on output confirmed that 80386/387 computers provided by The DPA Group and MOE were producing identical results for the same source run.[1] Exhibit A.2 presents this under the columns "AST80386" and "H-R80386", respectively.

As a final check on input data quality prior to model run execution, all source files (.SRC) were concatenated to a QC-file for manual proofing of all data values. Documentation is provided in Exhibit A.3. As runs were executed, successful

[1] Two computers were used to reduce the elapsed time needed for the dispersion modelling.

EXHIBIT A.2: COMPARISON OF CURRENT RUNS WITH PREVIOUS (1988) RUNS TORONTO VIRTUAL SOURCE

X	Y	AS180386	M-480386	TOR-PREV	% DIFFERENCE
-24000	-24000	0.001209	0.001209	0.001214	0.34
-20000	-24000	0.001069	0.001069	0.001072	0.35
-16000	-24000	0.002162	0.002162	0.002172	0.46
-12000	-24000	0.002518	0.002518	0.002527	0.37
-8000	-24000	0.003400	0.003400	0.003418	0.53
-4000	-24000	0.003876	0.003876	0.003890	0.36
0	-24000	0.005417	0.005417	0.005446	0.53
4000	-24000	0.006523	0.006523	0.006552	0.43
8000	-24000	0.009402	0.009402	0.009441	0.41
12000	-24000	0.007952	0.007952	0.007987	0.44
16000	-24000	0.006983	0.006983	0.007008	0.35
20000	-24000	0.005115	0.005115	0.005136	0.41
24000	-24000	0.003107	0.003107	0.003116	0.29
-24000	-20000	0.000787	0.000787	0.000789	0.22
-20000	-20000	0.001546	0.001546	0.001553	0.46
-16000	-20000	0.001486	0.001486	0.001493	0.45
-12000	-20000	0.002875	0.002875	0.002888	0.47
-8000	-20000	0.004774	0.004774	0.004793	0.40
-4000	-20000	0.003917	0.003917	0.003934	0.43
0	-20000	0.006968	0.006968	0.007013	0.65
4000	-20000	0.008294	0.008294	0.008339	0.53
8000	-20000	0.011138	0.011138	0.011192	0.49
12000	-20000	0.013250	0.013250	0.013329	0.59
16000	-20000	0.007045	0.007045	0.007084	0.54
20000	-20000	0.004144	0.004144	0.004159	0.36
24000	-20000	0.002810	0.002810	0.002819	0.31
-24000	-16000	0.000726	0.000726	0.000728	0.30
-20000	-16000	0.000934	0.000934	0.000937	0.35
-16000	-16000	0.002113	0.002113	0.002125	0.58
-12000	-16000	0.002423	0.002423	0.002437	0.59
-8000	-16000	0.004723	0.004723	0.004750	0.58
-4000	-16000	0.004473	0.004473	0.004507	0.76
0	-16000	0.009522	0.009522	0.009601	0.82
4000	-16000	0.012953	0.012953	0.013021	0.52
8000	-16000	0.014949	0.014949	0.015053	0.69
12000	-16000	0.008725	0.008725	0.008783	0.66
16000	-16000	0.005921	0.005921	0.005949	0.47
20000	-16000	0.004765	0.004765	0.004787	0.46
24000	-16000	0.003515	0.003515	0.003532	0.48
-24000	-12000	0.000947	0.000947	0.000951	0.37
-20000	-12000	0.001179	0.001179	0.001182	0.25
-16000	-12000	0.002415	0.002415	0.002434	0.79
-12000	-12000	0.003216	0.003216	0.003241	0.77
-8000	-12000	0.006173	0.006173	0.006232	0.94
-4000	-12000	0.009891	0.009891	0.010002	1.10
0	-12000	0.014386	0.014386	0.014545	1.09
4000	-12000	0.027545	0.027545	0.027799	0.91
8000	-12000	0.019971	0.019971	0.020138	0.83
12000	-12000	0.009426	0.009426	0.009489	0.66
16000	-12000	0.007316	0.007316	0.007362	0.63
20000	-12000	0.007238	0.007238	0.007286	0.65
24000	-12000	0.003968	0.003968	0.003985	0.44
-24000	-8000	0.000603	0.000603	0.000604	0.17
-20000	-8000	0.001510	0.001510	0.001517	0.47
-16000	-8000	0.001716	0.001716	0.001724	0.46
-12000	-8000	0.002700	0.002700	0.002721	0.77
-8000	-8000	0.005986	0.005986	0.006054	1.14
-4000	-8000	0.014066	0.014066	0.014239	1.21
0	-8000	0.026422	0.026422	0.026860	1.63
4000	-8000	0.043877	0.043877	0.044561	1.53

X	Y	AS180386	M-480386	TOR-PREV	% DIFFERENCE
8000	-8000	0.018208	0.018208	0.018397	1.03
12000	-8000	0.012210	0.012210	0.012332	0.99
16000	-8000	0.008286	0.008286	0.008345	0.70
20000	-8000	0.010383	0.010383	0.010457	0.71
24000	-8000	0.007427	0.007422	0.007473	0.61
-24000	-4000	0.001063	0.001065	0.001064	0.11
-20000	-4000	0.001160	0.001160	0.001162	0.19
-16000	-4000	0.001718	0.001718	0.001778	0.61
-12000	-4000	0.002024	0.002024	0.002034	0.49
-8000	-4000	0.005177	0.005177	0.005241	1.22
-4000	-4000	0.018469	0.018469	0.018891	2.23
0	-4000	0.079817	0.079817	0.082418	3.16
4000	-4000	0.056410	0.056410	0.057646	2.14
8000	-4000	0.020786	0.020786	0.029227	1.51
12000	-4000	0.021627	0.021627	0.021896	1.23
16000	-4000	0.011694	0.011694	0.011787	0.79
20000	-4000	0.009369	0.009369	0.009431	0.65
24000	-4000	0.007375	0.007375	0.007417	0.56
-24000	0	0.001217	0.001217	0.001221	0.33
-20000	0	0.001580	0.001580	0.001586	0.41
-16000	0	0.002189	0.002189	0.002200	0.31
-12000	0	0.003373	0.003373	0.003398	0.68
-8000	0	0.006401	0.006401	0.006466	1.01
-4000	0	0.020557	0.020557	0.020962	1.93
0	0	0.000000	0.000000	0.000000	
4000	0	0.175115	0.175115	0.181382	3.44
8000	0	0.056155	0.056155	0.057157	1.75
12000	0	0.029128	0.029128	0.029468	1.15
16000	0	0.018319	0.018319	0.018477	0.85
20000	0	0.012803	0.012803	0.012890	0.67
24000	0	0.009560	0.009560	0.009613	0.35
-24000	4000	0.001788	0.001788	0.001794	0.34
-20000	4000	0.002252	0.002252	0.002262	0.44
-16000	4000	0.003434	0.003434	0.003455	0.60
-12000	4000	0.008826	0.008826	0.008913	0.97
-8000	4000	0.010713	0.010713	0.010838	1.15
-4000	4000	0.029273	0.029273	0.029825	1.85
0	4000	0.114416	0.114416	0.118701	3.61
4000	4000	0.039103	0.039103	0.039912	2.03
8000	4000	0.031107	0.031107	0.031577	1.49
12000	4000	0.017739	0.017730	0.012925	1.04
16000	4000	0.013126	0.013126	0.013227	0.76
20000	4000	0.010210	0.010210	0.010268	0.57
24000	4000	0.007739	0.007739	0.007773	0.44
-24000	8000	0.003445	0.003445	0.003462	0.42
-20000	8000	0.002186	0.002186	0.002194	0.35
-16000	8000	0.003421	0.003421	0.003490	0.53
-12000	8000	0.005765	0.005765	0.005791	0.45
-8000	8000	0.009729	0.009729	0.009809	0.81
-4000	8000	0.022762	0.022762	0.023002	1.04
0	8000	0.037908	0.037908	0.038507	1.79
4000	8000	0.017312	0.017312	0.017599	1.63
8000	8000	0.012360	0.012360	0.012481	0.97
12000	8000	0.012792	0.012792	0.012902	0.85
16000	8000	0.010125	0.010125	0.010205	0.77
20000	8000	0.007424	0.007424	0.007474	0.64
24000	8000	0.005563	0.005563	0.005594	0.52
-24000	12000	0.001830	0.001830	0.001836	0.32
-20000	12000	0.002407	0.002407	0.002412	0.19
-16000	12000	0.004700	0.004700	0.004725	0.53

X	Y	AS180386	M-480386	TOR-PREV	% DIFFERENCE
-12000	12000	0.005116	0.005116	0.005140	0.47
-8000	12000	0.008391	0.008391	0.008443	0.61
-4000	12000	0.014704	0.014704	0.014854	1.01
0	12000	0.019960	0.019960	0.020213	1.15
4000	12000	0.009142	0.009142	0.009235	1.00
8000	12000	0.009090	0.009090	0.009175	0.93
12000	12000	0.006344	0.006344	0.006383	0.61
16000	12000	0.005964	0.005964	0.006002	0.61
20000	12000	0.005347	0.005347	0.005372	0.48
24000	12000	0.005379	0.005379	0.005407	0.51
-24000	16000	0.002365	0.002365	0.002369	0.19
-20000	16000	0.003862	0.003862	0.003880	0.46
-16000	16000	0.003231	0.003231	0.003241	0.31
-12000	16000	0.008528	0.008528	0.008564	0.42
-8000	16000	0.008134	0.008134	0.008170	0.41
-4000	16000	0.009683	0.009683	0.009764	0.83
0	16000	0.012703	0.012703	0.012811	0.84
4000	16000	0.005275	0.005275	0.005305	0.56
8000	16000	0.005697	0.005697	0.005745	0.84
12000	16000	0.003240	0.003240	0.003252	0.39
16000	16000	0.003981	0.003981	0.003998	0.43
20000	16000	0.003864	0.003864	0.003883	0.48
24000	16000	0.004374	0.004374	0.004393	0.41
-24000	20000	0.002331	0.002331	0.002338	0.29
-20000	20000	0.002263	0.002263	0.002268	0.21
-16000	20000	0.006075	0.006075	0.006099	0.39
-12000	20000	0.005532	0.005532	0.005538	0.47
-8000	20000	0.005788	0.005788	0.005819	0.52
-4000	20000	0.005400	0.005400	0.005429	0.54
0	20000	0.008973	0.008973	0.009032	0.65
4000	20000	0.005286	0.005286	0.005320	0.63
8000	20000	0.003087	0.003087	0.003100	0.42
12000	20000	0.003404	0.003404	0.003422	0.53
16000	20000	0.001819	0.001819	0.001822	0.16
20000	20000	0.002784	0.002784	0.002793	0.32
24000	20000	0.002819	0.002819	0.002830	0.40
-24000	24000	0.001697	0.001697	0.001700	0.15
-20000	24000	0.003712	0.003712	0.003725	0.33
-16000	24000	0.002641	0.002641	0.002648	0.27
-12000	24000	0.004558	0.004558	0.004568	0.22
-8000	24000	0.005184	0.005184	0.005208	0.45
-4000	24000	0.005242	0.005242	0.005267	0.48
0	24000	0.006777	0.006777	0.006812	0.32
4000	24000	0.003518	0.003518	0.003536	0.52
8000	24000	0.003136	0.003136	0.003152	0.49
12000	24000	0.002974	0.002974	0.002991	0.55
16000	24000	0.003190	0.003190	0.003205	0.47
20000	24000	0.001550	0.001550	0.001553	0.22
24000	24000	0.002084	0.002084	0.002089	0.25

NOTE:
- X and Y are coordinates in units of km.
- AS180386 refers to DPA computer.
- M 480386 refers to MOE computer.
- % Difference is 100*(Prev-Now)/Prev.
- All units are ug/m3 (per g/s emitted).

EXHIBIT A.3: CHECK -- IMPORT OF ELEVATED .SRC FILES

PLANT I.D.	PLANT NAME	X (m)	Y (m)	STACK HEIGHT (m)	STACK RADIUS (m)	STACK TEMP (oK)	EXIT VELOC. (m/s)	g/s	BLDG. HEIGHT (m)	BLDG. WIDTH (m)
600020	ABITIBI PRICE FWD	0	0	34.25	1.29	307	6.48	1	14	50
200056	BEAVER WOOD FIBRE	0	0	30.00	0.45	366	15.69	1	14	50
400004	CANADA CEMENT LAFARGE	0	0	46.00	0.75	358	30.70	1	14	50
400004	CANADA CEMENT LAFARGE	0	0	76.00	1.55	479	8.60	1	14	50
100031	C-I-L	0	0	32.00	1.50	472	21.70	1	14	50
300230	CANADA METAL CO. LTD.	0	0	46.00	0.90	352	31.36	1	14	50
202502	DOFASCO INC	0	0	44.00	3.05	477	5.09	1	14	50
202502	DOFASCO INC.	0	0	69.00	1.45	450	11.75	1	14	50
603005	DOMTAR PACKAGING LIMITED	0	0	30.00	0.45	366	3.00	1	14	50
503006	EDDY FOREST PRODUCTS	0	0	77.00	1.83	477	13.91	1	14	50
503006	EDDY FOREST PRODUCTS	0	0	31.00	0.92	341	5.60	1	14	50
100015	FEDERAL WHITE CEMENT LTD.	0	0	32.60	0.92	573	0.30	1	14	50
603007	GREAT LAKES FOREST	0	0	61.26	1.98	422	3.10	1	14	50
603007	GREAT LAKES FOREST	0	0	50.00	1.22	373	7.23	1	14	50
101303	IMPERIAL OIL	0	0	91.00	1.60	617	11.20	1	14	50
500004	KIDD CREEK MINES LTD.	0	0	43.00	0.61	355	27.70	1	14	50
500004	KIDD CREEK MINES LTD.	0	0	74.00	0.86	360	16.00	1	14	50
400029	LAKE ONTARIO CEMENT	0	0	37.00	1.20	450	26.20	1	14	50
400005	LENNOX GENERATING STATION	0	0	199.00	3.76	414	35.14	1	14	50
305801	LAKEVIEW GENERATING STATION	0	0	150.30	2.97	411	28.80	1	14	50
503001	MALLETTE KRAFT PULP&PAPER	0	0	38.40	0.46	332	14.69	1	14	50
205805	NANTICOKE GENERATING STATIO	0	0	198.10	2.75	394	30.50	1	14	50
400063	NITROCHEM (BROCKVILLE CHEMI	0	0	41.00	1.20	327	8.36	1	14	50
200055	ONTARIO PAPER CO. LTD.	0	0	41.70	0.54	358	25.70	1	14	50
301302	PETROCANADA CLARKSON	0	0	70.00	1.05	386	19.70	1	14	50
301302	PETROCANADA CLARKSON	0	0	51.00	1.05	491	34.80	1	14	50
101702	PETROSAR LTD.	0	0	61.00	1.40	441	6.40	1	14	50
101709	POLYSAR LTD.	0	0	91.50	2.82	443	20.00	1	14	50
100342	ST. MARY CEMENT	0	0	88.39	0.38	400	5.10	1	14	50
100342	ST. MARY CEMENT	0	0	55.78	0.84	450	18.10	1	14	50
101306	SUNCOR	0	0	77.72	1.68	610	4.93	1	14	50
101306	SUNCOR	0	0	38.10	0.73	542	3.78	1	14	50
201308	TEXACO CANADA (NANTICOKE)	0	0	112.00	3.05	506	8.60	1	14	50
201308	TEXACO CANADA (NANTICOKE)	0	0	56.00	1.05	584	4.50	1	14	50

termination was verified in each case and the number of valid/invalid met-cases compared with those recorded in the previous study for each met-zone.

A.6 DISCUSSION OF RESULTS

Comparison was made between previous study output and present study output for a virtual source in Toronto. Point by point comparison is presented in Exhibit A.2. "TOR-PREV" refers to the previous study, while "AST80386" and "H-R80386" refer to the present study. This showed that the doubling of building height and halving of building width resulted in output concentration data on the 4 km resolution grid that was within about $\pm$ 4% of previous results. This agreed with expectations for these sources confirming that the previous building source assumptions would yield representative dispersion footprints for most virtual sources in Ontario.

Output of several multi-source plants was tabulated via Lotus 123 and individual receptor concentrations inspected and compared. Anticipated trends in comparing high-elevated, moderately elevated, and virtual source-generated receptor concentrations were confirmed.

An example is provided in Exhibit A.4. While it is generally the case that annual average ambient concentrations resulting from virtual source assumptions exceed those resulting from elevated source assumptions (on the 24 x 24 km, 4 km resolution grid), it can be observed that for 10 - 15% of the receptors, the reverse is true.

Comparing elevated and virtual source effects on annual average ambient concentrations in this example:

EXHIBIT A.4: COMPARISON OF ELEVATED AND VIRTUAL SOURCES ON A 4-KM RECEPTOR GRID (PETROCANADA, CLARKSON)

Distances (Km)		Concentrations (ug/m3)			%Difference	%Difference
X	Y	70m Stack	51m Stack	Bldg.Wake	Bldg.-70m	Bldg.-51m
-24000	-24000	0.001112	0.000882	0.001209	8.05	27.09
-20000	-24000	0.001055	0.000828	0.001060	1.26	22.56
-16000	-24000	0.001306	0.001092	0.002162	39.59	49.48
-12000	-24000	0.001470	0.001234	0.002510	41.63	51.01
-8000	-24000	0.001564	0.001353	0.003400	53.99	60.22
-4000	-24000	0.002259	0.001923	0.003876	41.71	50.37
0	-24000	0.003163	0.002798	0.005417	41.61	48.35
4000	-24000	0.004537	0.003981	0.006523	30.44	38.97
8000	-24000	0.005133	0.004511	0.009402	45.40	52.02
12000	-24000	0.004771	0.004165	0.007952	40.00	47.62
16000	-24000	0.003251	0.002798	0.006983	53.44	59.93
20000	-24000	0.002864	0.002533	0.005115	44.01	50.48
24000	-24000	0.001719	0.001535	0.003107	44.69	50.60
-24000	-20000	0.001121	0.000940	0.000787	-42.47	-19.42
-20000	-20000	0.001327	0.001050	0.001546	14.16	32.06
-16000	-20000	0.001392	0.001096	0.001486	6.34	26.25
-12000	-20000	0.001813	0.001500	0.002875	36.94	47.82
-8000	-20000	0.002007	0.001634	0.004774	57.96	65.77
-4000	-20000	0.002441	0.002014	0.003917	37.69	48.59
0	-20000	0.003904	0.003395	0.006968	43.97	51.28
4000	-20000	0.005146	0.004459	0.008294	37.96	46.24
8000	-20000	0.005473	0.004764	0.011138	50.86	57.23
12000	-20000	0.005433	0.004566	0.013250	59.00	65.54
16000	-20000	0.003770	0.003290	0.007045	46.49	53.30
20000	-20000	0.002157	0.001891	0.004144	47.95	54.36
24000	-20000	0.002197	0.001990	0.002810	21.83	29.10
-24000	-16000	0.000850	0.000689	0.000726	-17.06	5.11
-20000	-16000	0.001377	0.001138	0.000934	-47.48	-21.83
-16000	-16000	0.001650	0.001303	0.002113	21.53	38.35
-12000	-16000	0.001816	0.001410	0.002423	25.04	41.80
-8000	-16000	0.002250	0.001808	0.004723	52.19	61.72
-4000	-16000	0.002547	0.002125	0.004473	43.06	52.50
0	-16000	0.005026	0.004269	0.009522	47.22	55.17
4000	-16000	0.006273	0.005159	0.012953	51.57	60.17
8000	-16000	0.006803	0.005610	0.014940	54.50	62.47
12000	-16000	0.004487	0.003804	0.008725	48.01	56.40
16000	-16000	0.002832	0.002427	0.005921	52.17	59.01
20000	-16000	0.002609	0.002316	0.004765	45.25	51.40
24000	-16000	0.002456	0.002313	0.003515	30.14	34.21
-24000	-12000	0.001093	0.000945	0.000947	-15.34	0.21
-20000	-12000	0.001200	0.000985	0.001179	-1.77	16.51
-16000	-12000	0.001610	0.001294	0.002415	33.34	46.42

Distances (Km)		Concentrations (ug/m3)			%Difference	%Difference
X	Y	70m Stack	51m Stack	Bldg.Wake	Bldg.-70m	Bldg.-51m
-12000	-12000	0.002227	0.001717	0.003216	30.75	46.59
-8000	-12000	0.002682	0.002092	0.006173	56.55	66.11
-4000	-12000	0.003280	0.002595	0.009891	66.84	73.76
0	-12000	0.006887	0.005651	0.014386	52.13	60.72
4000	-12000	0.010228	0.008283	0.027545	62.87	69.93
8000	-12000	0.006957	0.005404	0.019971	65.16	72.49
12000	-12000	0.003968	0.003301	0.009428	57.91	64.98
16000	-12000	0.003292	0.002939	0.007316	54.99	59.82
20000	-12000	0.003242	0.002961	0.007238	55.21	59.10
24000	-12000	0.002271	0.002108	0.003968	42.78	46.88
-24000	-8000	0.001433	0.001187	0.000603	-137.61	-96.75
-20000	-8000	0.001413	0.001187	0.001510	6.40	21.36
-16000	-8000	0.001735	0.001428	0.001714	-1.24	16.80
-12000	-8000	0.001985	0.001503	0.002700	26.50	44.32
-8000	-8000	0.003365	0.002493	0.005986	43.78	58.36
-4000	-8000	0.004443	0.003246	0.014066	68.41	76.92
0	-8000	0.010417	0.008091	0.026422	60.57	69.38
4000	-8000	0.012104	0.009057	0.045877	73.62	80.26
8000	-8000	0.006153	0.004932	0.018208	66.20	72.91
12000	-8000	0.005442	0.004837	0.012210	55.43	60.39
16000	-8000	0.003785	0.003429	0.008266	54.32	58.62
20000	-8000	0.003599	0.003220	0.010383	65.33	68.99
24000	-8000	0.003629	0.003262	0.007427	51.14	56.08
-24000	-4000	0.002436	0.002143	0.001063	-129.16	-101.56
-20000	-4000	0.002484	0.002154	0.001160	-114.08	-85.64
-16000	-4000	0.002602	0.002174	0.001710	-51.48	-26.50
-12000	-4000	0.003077	0.002409	0.002024	-52.01	-18.99
-8000	-4000	0.003544	0.002670	0.005177	31.54	48.42
-4000	-4000	0.006237	0.004228	0.018469	66.23	77.11
0	-4000	0.018378	0.013025	0.079817	76.98	83.68
4000	-4000	0.011597	0.008983	0.056410	29.44	84.11
8000	-4000	0.008590	0.007391	0.028786	70.13	74.32
12000	-4000	0.007441	0.006284	0.021627	65.59	70.94
16000	-4000	0.005532	0.004644	0.011694	52.69	60.29
20000	-4000	0.004300	0.003754	0.009369	54.11	59.93
24000	-4000	0.003368	0.002940	0.007375	54.34	60.03
-24000	0	0.002385	0.002244	0.001217	-96.06	-84.49
-20000	0	0.002995	0.002790	0.001580	-89.62	-76.61
-16000	0	0.003934	0.003616	0.002189	-79.76	-65.24
-12000	0	0.005535	0.005001	0.003375	-63.96	-48.18
-8000	0	0.008732	0.007736	0.006401	-36.42	-20.85
-4000	0	0.017154	0.015082	0.020557	16.55	26.63

EXHIBIT A.4: COMPARISON OF ELEVATED AND VIRTUAL SOURCES ON A 4-KM RECEPTOR GRID (PETROCANADA, CLARKSON) (Continued)

Distances (Km) X	Y	Concentrations (ug/m3) 70m Stack	51m Stack	Bldg.Wake	%Difference Bldg.-70m	%Difference Bldg.-51m
0	0	0.000000	0.000000	0.000000	0.00	0.00
4000	0	0.025403	0.019856	0.175115	85.49	88.66
8000	0	0.014218	0.011426	0.056155	74.68	79.66
12000	0	0.009608	0.007906	0.029128	67.02	72.86
16000	0	0.007175	0.006022	0.018319	60.84	67.13
20000	0	0.005684	0.004846	0.012803	55.60	62.15
24000	0	0.004682	0.004040	0.009560	51.02	57.74
-24000	4000	0.002609	0.002293	0.001788	-45.94	-28.23
-20000	4000	0.003052	0.002631	0.002252	-35.52	-16.84
-16000	4000	0.003397	0.002912	0.003434	1.09	15.21
-12000	4000	0.005004	0.004234	0.008828	43.31	52.03
-8000	4000	0.006102	0.004742	0.010713	43.04	55.74
-4000	4000	0.008594	0.006233	0.029273	70.64	78.71
0	4000	0.012498	0.008917	0.114416	89.08	92.21
4000	4000	0.016936	0.013677	0.039103	56.69	65.02
8000	4000	0.014812	0.012574	0.031107	52.38	59.58
12000	4000	0.010551	0.008959	0.017739	40.52	49.50
16000	4000	0.007176	0.006122	0.013126	45.33	53.36
20000	4000	0.005623	0.004741	0.010210	44.93	53.56
24000	4000	0.005244	0.004488	0.007739	32.21	42.00
-24000	8000	0.002223	0.001954	0.003445	35.47	43.29
-20000	8000	0.003091	0.002675	0.002186	-41.40	-22.34
-16000	8000	0.003030	0.002457	0.003471	12.71	29.23
-12000	8000	0.004197	0.003338	0.005765	27.21	42.11
-8000	8000	0.004652	0.003676	0.009729	52.18	62.22
-4000	8000	0.006703	0.005120	0.022262	70.55	77.51
0	8000	0.007516	0.005564	0.037908	80.70	85.32
4000	8000	0.007075	0.005729	0.017312	59.13	66.91
8000	8000	0.008141	0.006864	0.012360	34.14	44.47
12000	8000	0.007884	0.006724	0.012792	38.38	47.44
56000	8000	0.006572	0.005794	0.010125	35.10	42.77
20000	8000	0.005991	0.005153	0.007424	19.30	30.60
24000	8000	0.004628	0.004064	0.005565	16.85	26.97
-24000	12000	0.001956	0.001618	0.001830	-6.88	11.59
-20000	12000	0.002683	0.002271	0.002407	-11.45	5.65
-16000	12000	0.003117	0.002587	0.004700	33.68	44.96
-12000	12000	0.003060	0.002546	0.005116	40.18	50.23
-8000	12000	0.004517	0.003458	0.008391	48.56	58.79
-4000	12000	0.004556	0.003706	0.014704	69.01	74.79
0	12000	0.005078	0.004029	0.019980	74.58	79.83
4000	12000	0.004667	0.003785	0.009142	48.95	58.60
8000	12000	0.004800	0.004089	0.009090	47.20	55.02
12000	12000	0.005000	0.004326	0.006344	21.19	31.81
16000	12000	0.004934	0.004277	0.005964	17.26	28.31
20000	12000	0.005246	0.004610	0.005347	1.88	13.78
24000	12000	0.003994	0.003579	0.005379	25.76	33.47
-24000	16000	0.002144	0.001851	0.007365	9.26	21.73
-20000	16000	0.002309	0.001925	0.003862	40.21	50.15
-16000	16000	0.002233	0.001919	0.003231	30.88	40.59
-12000	16000	0.003579	0.002996	0.008128	54.03	64.87

Distances (Km) X	Y	Concentrations (ug/m3) 70m Stack	51m Stack	Bldg.Wake	%Difference Bldg.-70m	%Difference Bldg.-51m
-8000	16000	0.003766	0.003106	0.008136	53.68	61.82
-4000	16000	0.003114	0.002598	0.009683	67.84	73.17
0	16000	0.003864	0.003158	0.012703	69.58	75.14
4000	16000	0.003139	0.002552	0.005275	40.50	51.62
8000	16000	0.003304	0.002792	0.005697	42.00	51.00
12000	16000	0.003607	0.003191	0.003240	-11.35	1.51
16000	16000	0.003468	0.003048	0.003981	12.87	23.43
20000	16000	0.003755	0.003374	0.003864	2.81	12.66
24000	16000	0.003539	0.003170	0.004374	19.10	22.54
-24000	20000	0.002014	0.001796	0.002331	13.60	22.96
-20000	20000	0.001735	0.001524	0.002263	23.33	32.69
-16000	20000	0.002632	0.002171	0.006075	56.67	64.26
-12000	20000	0.003354	0.002796	0.005532	39.38	49.46
-8000	20000	0.002210	0.002379	0.005768	53.10	58.89
-4000	20000	0.002858	0.002387	0.005400	47.07	55.80
0	20000	0.003115	0.002601	0.008973	65.28	71.01
4000	20000	0.002998	0.002494	0.005286	43.28	52.83
8000	20000	0.002570	0.002122	0.003087	16.75	31.25
12000	20000	0.002934	0.002550	0.003404	13.80	25.07
16000	20000	0.002975	0.002634	0.001819	-63.49	-44.79
20000	20000	0.002587	0.002295	0.002784	7.10	17.57
24000	20000	0.002857	0.002640	0.002819	-1.35	6.36
-24000	24000	0.001407	0.001253	0.001697	17.13	26.19
-20000	24000	0.002122	0.001776	0.003712	42.84	52.17
-16000	24000	0.002209	0.001888	0.002641	16.36	28.51
-12000	24000	0.002671	0.002272	0.004558	41.39	50.15
-8000	24000	0.002388	0.002056	0.005184	53.93	60.30
-4000	24000	0.002595	0.002147	0.005242	50.49	59.04
0	24000	0.002611	0.002215	0.006777	61.46	67.31
4000	24000	0.002699	0.002267	0.003518	23.28	35.55
8000	24000	0.002332	0.002026	0.003136	25.64	35.39
12000	24000	0.002084	0.001785	0.002974	29.95	39.99
16000	24000	0.002160	0.001938	0.003190	31.65	39.23
20000	24000	0.002687	0.002432	0.001550	-73.39	-56.91
24000	24000	0.002025	0.001808	0.002084	2.82	13.24

Q.C. CHECK PETROCANADA, CLARKSON .SRC FILES

PLANT I.D.	PLANT NAME	X (m)	Y (m)	STACK HEIGHT (m)	STACK RADIUS (m)	STACK TEMP. (oK)	EXIT VELOC. (m/s)	g/s	BLDG. HEIGHT (m)	BLDG. WIDTH (m)
301302	PETROCANADA CLARKSON	0	0	70.00	1.05	386	19.70	1	14	50
301302	PETROCANADA CLARKSON	0	0	51.00	1.05	491	34.80	1	14	50
301302	GEN BLDG SOURCE	0	0	14.00	0.50	-999	0.00	1	14	50

- For half to two thirds of the receptors, elevated source results are within a factor of 2 of the virtual source results.

- The largest absolute differences and larger % differences occur at the receptor locations nearest the source.

- The smallest absolute differences and largest % differences tend to occur near the grid perimeter.

- 98% of the receptor grid concentrations resulting from virtual source assumptions fall within the same order of magnitude as those resulting from elevated source assumptions.

- The taller stack always yields marginally higher resultant concentrations than the shorter (intermediate) stack. This would not generally be the case but can in this instance be attributed to the higher buoyancy and plume rise of the shorter stack.

A.7 SUMMARY

In a previous study to estimate the public benefits of proposed changes to Regulation 308, extensive development of representative meteorology for the entire Province of Ontario was carried out. Dispersion modelling was performed yielding annual average ambient concentration grids. Additional data were mapped in and key benefits were determined to be attributable to reductions in SO_2 and particulate emissions.

The present study took a closer look at SO_2 and particulate emissions. A statistically representative sampling of emitters of these pollutants was made and detailed source characteristics obtained. Data reduction was carried out and model runs were executed.

Results were compared with the previous study. Additional data were mapped in and comparable benefits determined.

APPENDIX B

Exposure-Response Functions

B.1 INTRODUCTION

An exposure-response function predicts how health and other factors, such as visibility and materials damage, change as the concentration of a contaminant changes. Exposure-response functions are available for health effects, materials damage and visibility due to sulphur dioxide and suspended particulate matter emissions.

B.2 SULPHUR DIOXIDE FUNCTIONS

B.2.1 Mortality

An exposure-response function is available for deaths attributable to sulphur dioxide. The function calculates absolute change in the number of annual deaths.

$$\text{Deaths}^{1} = 1.670 \times 10^{-5} \times POP \times (SO_{2A}-SO_{2B})$$

Where:

SO_{2A}	=	The SO_2 concentration for a grid cell under existing regulations.
SO_{2B}	=	The SO_2 concentration for a grid cell under a specific implementation scenario.
POP	=	The population of a grid cell.

[1] Note the coefficient has been changed from that used in the previous study to correct an arithmetic error in the derivation of the function caused by the selection of an incorrect coefficient from a table of regression results.

The function presented above is the central case estimate for reduction in annual mortality due to reduced concentrations of sulphur dioxide. The low case is calculated by applying the lower bound estimate of the value of a statistical life to the calculated reduction in mortality.

B.2.2 Hospital Days for Respiratory Conditions

The function of hospital days for respiratory conditions (HDRC) is:

$$HDRC = 4.0 \times 10^{-4} \times (SO_{2A} - SO_{2B}) \times POP$$

The variables SO_{2A}, SO_{2B} and POP have the same meaning as in the mortality equation.

The lower bound estimate is obtained by replacing 4.0×10^{-4} in the central case equation presented above with 1.5×10^{-4}. In other words the lower bound is 0.375 times the central case.

B.2.3 Hospital Admissions for Respiratory Disease

The function for hospital admissions for respiratory disease (HARD) is:

$$HARD = 4.065 \times 10^{-5} \times (SO_{2A} - SO_{2B}) \times POP$$

The variables SO_{2A}, SO_{2B} and POP have the same meaning as in the mortality equation.

The lower bound estimate is calculated by replacing 4.065×10^{-5} in the central case equation presented above with 0.63×10^{-5}. Alternately, the lower bound is 0.155 times the central case.

B.3 PARTICULATE MATTER FUNCTIONS

Six exposure response functions exist for PM. They relate to:

- death;
- emergency room visits;
- restricted activity days;
- chronic obstructive pulmonary disease;
- visibility; and
- materials damage.

In each of the functions presented below the symbols have the following definitions.

PM_A	=	The original PM concentration for a grid cell.
PM_B	=	The PM concentration for a grid cell under the scenario considered.
E	=	The mean 1986 rate of exchange (1.3894) to convert 1986 U.S. to 1986 Canadian dollars.
HF	=	A factor (2.8) to convert the population of a grid cell to the number of households.
POP	=	The population of a grid cell.

B.3.1 Death

$$\text{Deaths} = 2.21 \times 10^{-6} \times POP \times (PM_A - PM_B)$$

This equation gives the change in annual deaths due to a change in particulate matter concentration. The lower bound and central value are calculated by applying the corresponding values of a statistical life to the reduction in annual mortality estimated using the above equation.

B.3.2 Emergency Room Visits

$$ERV = 1.3 \times 10^{-4} \times POP \times (PM_A - PM_B)$$

The change in the number of emergency room visits per year, ERV, is related to the change in particulate matter concentration. The lower bound estimate of emergency room visits is calculated by replacing the central case coefficient of 1.3×10^{-4} by 1.2×10^{-5}.

B.3.3 Restricted Activity Days

$$RAD = 2.736 \times 10^{-2} \times POP \times (PM_A - PM_B) - \text{Emergency Room Visits}$$

The change in the number of restricted activity days, RAD, is reduced by the change in the number of emergency room visits (ERV) to avoid double counting. The lower bound estimate of restricted activity days is calculated by replacing the central case coefficient of 2.736×10^{-2} by 1.938×10^{-2}. In other words, the lower bound is equal to 0.70833 times the central case.

B.3.4 Visibility Effects

$$\text{Total Value Per Year} = E \times 206 \times \ln (PM_A/PM_B) \times POP/HF$$

The lower bound estimate is calculated as 0.5 times the central case.

This function returns an annual dollar value for improved visibility.

B.3.5 Materials Damage

Total Value
Per Year $= E \times 7.4 \times (PM_A - PM_B) \times POP/HF$

This function also returns an annual dollar value of reduced materials damage.

To get the lower bound estimate, the central case coefficient of 7.4 is replaced by 0.52. In other words, the lower bound is 0.07027 times the central case.

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APPENDIX C

Regulation 308 Implementation Scenarios

REGULATION 308 IMPLEMENTATION SCENARIOS

Five implementation scenarios for the proposed revisions to Regulation 308 are defined in terms of level of control technology and implementation date. The proposed revisions to Regulation 308 identify three levels of control technology that can be applied to different categories of contaminants. They are:

- LAER, or Lowest Achievable Emission Rate (the most stringent form of control);
- BACT, or Best Available Control Technology; and
- NSPS, or New Source Performance Standards (the least stringent control).

The Discussion Paper does not define these levels of control explicitly, but suggests that the corresponding control technology in the United States provides a useful reference point. Senes defined the specific control technologies and corresponding emissions that form the basis for this analysis. The interested reader is referred to their report for further details.

The implementation scenarios specify the level of control to be applied to each category of contaminants. Exhibit C.1 shows the proposed level of control for each contaminant type by scenario. There are more LAER controls in Scenario B where stringent emission controls are considered, and more NSPS controls under the less stringent control scenario (Scenario C).

Scenario D is defined using two levels of control rather than three levels as assumed in Scenario A. In practice Scenarios A and D are the same. The contaminants governed by less stringent controls in Scenario A are usually found in emission streams to which more stringent controls must be applied, so they are also controlled at this more stringent level. Scenario E is the same as Scenario A

EXHIBIT C.1: PROPOSED SCENARIOS

SCENARIO	A Initial	B More Stringent	C Less Stringent	D 2 Tier
CONTAMINANT GROUP				
Volatile Organic Compounds				
Chlorinated	LAER	LAER	BACT	LAER
Aliphatics	NSPS	BACT	NSPS	BACT
Aromatics	BACT	LAER	NSPS	BACT
Esters/Alcohols/Esthers/ Aldehydes/Ketones	BACT	LAER	NSPS	BACT
Mercaptans	NSPS	BACT	NSPS	BACT
Particulates Associated				
Organics	LAER	LAER	BACT	LAER
Metals	LAER	LAER	BACT	LAER
Other Particulates	BACT	LAER	NSPS	BACT
Semi-Volatile Organics	BACT	LAER	NSPS	BACT
Pesticides	BACT	LAER	NSPS	BACT
Corrosives				
Acids	BACT	LAER	NSPS	BACT
Bases	BACT	LAER	NSPS	BACT
Other	BACT	LAER	NSPS	BACT
Other	BACT	LAER	NSPS	BACT

IMPLEMENTATION

SCENARIO	A,B,C,D	E*
New Facilities	1989	1989
Existing Facilities		
Contaminant Group:		
LAER	1994	2004
BACT	1994	2009
NSPS	1999	2014

* Same as Scenario A except for implementation schedule.

except for the implementation schedule. The estimated emissions provided by Senes for Scenario E correspond to the first phase of the implementation schedule for Scenario A.

These control scenarios were developed in consultation with the Ministry of the Environment. Information on the different levels of control technology is available in the MOE Discussion Paper. The Senes report specifies the control technology assumed for each contaminant group and industry sector. It also estimates the resulting emissions by contaminant for each scenario.